WATER QUALITY SUMMARY

for the

EASTERN RIVERS AND MOUNTAINS NETWORK

by:

Scott Sheeder, Barry Evans and Kenneth Corradini

Pennsylvania State University
Institutes of the Environment
001 Land and Water Building
University Park, PA 16802
(814) 863-0291

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EXECUTIVE SUMMARY

Water is a major natural resource of the nine ERMN parks, and NPS mandates clearly state the need to protect water resources. The NPS Strategic Plan 2001-2005 provides goals and guidelines for water quality. In the Omnibus Management Act of 1998, Congress required that park managers provide a "program of inventory and monitoring of the National Park System resources."

This report was prepared to meet the policy and regulatory portion of the water resource information and assessment needs of the Eastern Rivers and Mountains Network (ERMN). Water quality standards of the four network states—Pennsylvania, West Virginia, New York and New Jersey—were reviewed and summarized. Other materials reviewed include park "Baseline Water Quality Data Inventory and Analysis" reports (a.k.a Horizon Reports), current state lists of impaired water bodies (303(d) lists), current data retrieved from STORET, etc. As part of these reports, information pertaining to site characteristics, past and current water quality problems, existing water quality monitoring stations and stream gages, and past and current water quality monitoring studies were summarized.

A Brief synopsis of each of the reports is provided below and in Table 1 with the full report for each Park presented in Appendix G.

The primary conclusions of assessment are:

- Surface waters within the West Virginia and Delaware River National Parks have been impaired by fecal coliform bacteria. Short-circuiting and/or absent sewage treatment systems are the likely cause of this impairment
- Acid mine drainage has impaired waters within the West Virginia National Parks, JOFL, and FRHI
- The Delaware River National Parks have a human health fish consumption advisory, and are listed on the PA 303d list for mercury and PCB contamination. These constituents been identified in fish tissue, and do not imply elevated concentrations in the water column
- Very limited water quality information is available for ALPO, FONE, JOFL, and FRHI. A phase one assessment of ALPO and JOFL is currently being conducted for the NPS by Penn State University

Table 1. Summary of surface water body designations and impairments for parks within the Eastern Rivers and Mountains Network.

Park Name	State	Miles of Rivers and Streams	303(d) Listed Streams (no.)	Impaired Length (stream-mi)	Criteria Affected	Cause	Streams with High Quality Designations (no.)	High Quality Miles (stream-mi)
Delaware Water Gap National Recreation Area	PA/NJ	178.59	4	59.48	Arsenic, Benthic Macroinvertebrates, Cadmium, Chromium, Copper, Dissolved Oxygen, Dissolved Solids, Fecal Coliform, Lead, Mercury, Nickel, Nitrate, PCB, pH, Phosphorus, Selenium, Silver, Temperature, Total Suspended Solids, Unionized Ammonia, Zinc	Unknown, N/A	46 in PA, 24 in NJ	66.69
Upper Delaware Scenic And Recreational River	PA/NY	221.41	2	75.59	Mercury, PCB	Unknown	50 in PA, N/A in NY[1]	37.71
Johnstown Flood National Memorial	PA	0.89	1	0.57	Metals, pH	Abandoned Mine Drainage	0	0.00
Allegheny Portage Railroad National Historic Site	PA	5.25	0	0	None	None	0	0.00
Fort Necessity National Battlefield	PA	3.72	0	0	None	None	8	3.72
Friendship Hill National Historic Site	PA	1.58	0	0	None	None	0	0.00
Gauley River National Recreation Area	WV	45.51	3	31.8	Aluminum (dis), Fecal Coliform, Iron, Manganese	Mine Drainage, Unknown	8	34.19
New River Gorge National River	WV	164.54	14	76.1	Aluminum (dis), CNA-Biological, Fecal Coliform, Iron, Manganese, pH	Mine Drainage, Unknown	13	83.73
Bluestone National Scenic River	WV	17.57	3	12.7	Fecal Coliform	Unknown	3	12.40

[1] New York does not have a "High Quality" designation.
Note: All values based on streams located within the park boundaries.

Brief Park Summaries:

Bluestone National Scenic River (WV): The contributing watershed is approximately 433 mi^2 in size with roughly 17.7 miles of streams contained within the park boundary. Of the total river miles within park boundaries, 12.4 miles are designated as "high quality". Overall, surface waters within the park boundary appear to be impacted principally by bacteria and trace metals. Approximately 12.7 miles of streams within the park have been determined by the West Virginia DEP to be impaired by fecal coliform from unknown sources. Although not specifically listed, mine drainage may also be contributing to water quality problems in the park based on an analysis of recent water quality monitoring data. No TMDLs have been developed for any of the "303d-listed" waters within the park, and TMDLs for these streams are not scheduled to be completed until 2007. In anticipation of future TMDL activities, it was recommended that at least three water quality monitoring stations be established at or near the locations of older stations that have since been discontinued, and that these stations be set up to sample for fecal coliform and various mine drainage-related parameters. Currently, there are no active water quality monitoring stations and one active USGS stream gage within or near the park boundary that could be utilized in a monitoring program.

New River Gorge National River (WV): The contributing watershed is approximately 6,952 mi^2 in size with roughly 166 miles of streams contained within the park boundary. Of the total river miles within park boundaries, 84 miles are designated as "high quality". Overall, surface waters within the park boundary appear to be impacted principally by bacteria and trace metals. Approximately 73 miles of streams within the park have been determined by the West Virginia DEP to be impaired by fecal coliform, mine drainage, or to be otherwise biologically impaired due to unknown sources. No TMDLs have been developed for any of the "303d-listed" waters within the Lower New River watershed, including those within the New River Gorge NR. The West Virginia DEP plans to develop TMDLs for all waters in the park by the end of 2007, with the exception of the dissolved aluminum TMDL for the New River, which is scheduled to be completed by 2017. In anticipation of future TMDL activities, it was recommended that at least 18 water quality monitoring stations be established at or near the locations of older stations that have since been discontinued. It was suggested that most of these stations be set up to sample for fecal coliform and various mine drainage-related parameters. It was also suggested that various other stations be set up to sample for dissolved oxygen, nutrients, and sediment as well. Currently, there are no active water quality monitoring stations and 2 active USGS stream gages within or near the park boundary that could be utilized in a monitoring program.

Gauley River National Recreation Area (WV): The contributing watershed is approximately 1315 mi^2 in size with roughly 45.9 miles of streams contained within the park boundary. Of the total river miles within park boundaries, 32.2 miles are designated as "high quality". Overall, surface waters within the park boundary appear to be impacted principally by bacteria and trace metals. Approximately 31.8 miles of streams within the park have been determined by the West Virginia DEP to be impaired by fecal coliform, iron and manganese from mine drainage, and mercury and dissolved aluminum from unknown sources (most likely mine drainage). No TMDLs have been developed for any of the "303d-listed" waters within the Gauley River watershed, including those within the Gauley River NRA. Currently, the West Virginia DEP has plans to develop TMDLs for all of these impaired waters (with some exceptions) by the end of

2006. The three exceptions are the Gauley River itself, the Meadow River, and the Summersville Lake/Reservoir. The TMDLs for these three impaired waters are not scheduled to be completed until 2016. There is currently one existing water quality station located at the downstream end of the park that appears to monitor for a fairly complete suite of trace metals, algae, nutrients, acidity, pH, temperature, dissolved oxygen, specific conductance, and more recently, total suspended solids and fecal coliform. Additionally, the DEP has also established a short-term station near an older site that could be used to support any analyses done for Peter's Creek. This station is currently being used by DEP to monitor for a suite of AMD-related contaminants as well as for fecal coliform. It has been recommended that at least two more stations be established on the Gauley and Meadow Rivers. For the Gauley River, focus should be placed on monitoring contaminants related to mine drainage (e.g., Fe, Al, Mn, and pH). For the Meadow River, emphasis should be placed on monitoring pH levels. Currently, there is one active water quality monitoring station and 4 active USGS stream gages within or near the park boundary that could be utilized in a monitoring program.

Allegheny Portage Railroad National Historic Site (PA): The Allegheny Portage Railroad National Historic Site (ALPO) is actually comprised of two separate parcels. The easternmost parcel is referred to as the "Main Unit", and the westernmost parcel is referred to as the "Staple Bend Unit". The contributing watersheds are approximately 17.4 mi^2 and 179 mi^2 in size with roughly 32 miles and less than on mile of streams contained within Main Unit and Staple Bend Unit, respectively. No portions of the surface water bodies contained within park property are designated as "high quality". Overall, surface waters within the park boundary appear to be in good condition. There are no surface water bodies contained within either section of the park that are currently included on Pennsylvania's 303d list of impaired water bodies. Consequently, there are no plans to develop any TMDLs for streams within, or that flow through, the park. Water quality data collected in the 1990s, however, suggest acidic deposition or mine drainage may be adversely impacting surface water conditions in the Blair Gap Run located in the main unit of the park. There are currently no long-term water quality or discharge monitoring stations located in or near the park. However, as part of a current "Phase 1" monitoring project being completed for the National Park Service by Penn State University, water quality data are being collected at various locations within the eastern section. More specifically, samples are being taken at 6 different locations along Blair Gap Run that flows through the site. Data being collected include in-stream measurements of alkalinity, pH, specific conductivity, dissolved oxygen, temperature, instantaneous stream discharge, selected toxics (e.g., cyanide and mercury), nutrients (N and P), turbidity, and fecal coliform.

Johnstown Flood National Memorial (PA): The contributing watershed is approximately 53 mi^2 in size with roughly 1 mile of streams contained within the park boundary. There are no specially designated (i.e. 'high quality') streams within the park property. Overall, the South Fork of the Little Conemaugh has been heavily impacted due to acid mine drainage upstream of the park property. Several tributaries to the South Fork of the Little Conemaugh flowing through park property appear to be in good condition. At present, the entire length of the South Fork Little Conemaugh contained within the park has been included on Pennsylvania's 303d list of impaired water bodies. In this case, the stream has been determined to be impaired by pH and metals originating from abandoned mine drainage. While no specific data has been set, the TMDL assessment for this reach will be completed no later than 2015. There are currently no long-term water quality or discharge monitoring stations located in or near the park. However, as part of a current "Phase 1" monitoring project being completed for the National Park Service by Penn State University, water quality data are being collected at various locations within the park. More specifically, samples are being taken at five different locations along the South Fork Little Conemaugh River that flows through the site and some of its tributaries. Data being collected include in-stream measurements of alkalinity, pH, specific conductivity, dissolved oxygen, temperature, instantaneous stream discharge, selected toxics (e.g., cyanide and mercury), nutrients (N and P), turbidity, and fecal coliform

Fort Necessity National Battlefield (PA): The Fort Necessity National Battlefield (FONE) park is actually comprised of three separate parcels, including the main park area and the Jumonville Glen and Braddock's Grave units to the north. The Jumonville Glen unit contains no streams. The main park area and Braddock's Grave contain headwater tributaries of Scott's Run and Meadow Run, and Braddock Run, respectively. All of these streams (3.72 miles) are designated at high quality streams. Overall, surface waters within the park boundary appear to be in good condition. There are no surface water bodies contained within any of the three park units that are currently included on Pennsylvania's 303d list of impaired water bodies. Consequently, there are no plans to develop any TMDLs for streams within, or that flow through, the park. However, past water quality records have shown that in-stream zinc concentrations within Meadow Run downstream of the main park unit exceeded the acute freshwater criterion of 120 µg/L from 1974 through 1994. For this reason, it was recommended that a limited amount of sampling be conducted on the tributary stream that exits the main park area. In addition to zinc, other "Level 1" parameters such as alkalinity, pH, specific conductivity, dissolved oxygen, temperature, instantaneous stream discharge, nutrients (N and P), turbidity, and fecal coliform should also be collected for the purpose of assessing potential water quality problems associated with this section of the park. Currently, there are no active water quality or discharge monitoring stations within or near the park boundary that could be utilized in a monitoring program.

Friendship Hill National Historic Site (PA): The contributing watershed is approximately 1.4 mi^2 in size with roughly 1.7 miles of streams contained within the park boundary. There are no specially designated (i.e. 'high quality') streams within the park property. Overall, surface waters within the park boundary appear to be impacted principally by pH and trace metals. Neither of these streams has been assessed for biological impairment by the Pennsylvania Department of Environmental Protection. Consequently, these streams are not listed on the PA 303d list as either impaired or attaining their aquatic use designation, and there are currently no plans for TMDL development. A previous water quality assessment (Horizon report) and an analysis of current water quality data suggest that the two streams that flow through the park property have been heavily impacted by acid mine drainage. Between 1990 and 2004, water quality samples collected at sites on these two streams show pH values ranging between 2.41 and 3.54, and aluminum concentrations of 23,150 – 111,000 ug/L. For this reason it was recommended that sampling for pH and dissolved metals be conducted on both streams within the park. Additionally, NPS employees may wish to periodically contact the PA Department of Environmental Protection's Office of Water and Wastewater to check on the status of stream assessment and/or TMDL development. Currently, there are no active water quality or discharge monitoring stations within or near the park boundary that could be utilized in a monitoring program.

Delaware Water Gap National Recreation Area (PA and NJ): The contributing watershed is approximately 4167 mi^2 in size with roughly 200 miles of streams contained within the park boundary. Of the total river miles within park boundaries, 139 miles designated as “high quality” (“Outstanding National Resource” is the equivalent NJ designation). Overall, surface waters within the park boundary appear to be good quality for aquatic health and recreational uses. Approximately 60 miles of streams within the park are currently listed as impaired on the New Jersey and Pennsylvania 303d lists. The impaired water bodies, including the Delaware River, Bushkill and Dunnfield Creeks and Flat Brook listed as impaired due to nutrients, metals, organics, physical parameters (dissolved oxygen, temperature, etc.), and other factors, all of unknown origin. There is a fish consumption advisory in effect for the Delaware River, due to elevated levels of mercury and PCBs in fish tissue. None of the impaired water bodies are scheduled for TMDL assessment within the next several years. An analysis of 1990 to 2004 water quality data indicates that phosphorus, bacteria, and pH appear to be the water quality constituents of principle concern. With respect to current monitoring within the park, many discharge and water chemistry stations have been discontinued over the last decade. Currently the USGS and NPS are conducting an extensive, short-term tributary analysis within the park. Currently, there are 4 active long-term water quality monitoring stations and 6 active USGS stream gages within or near the park boundary that could be utilized in a monitoring program.

Upper Delaware Scenic and Recreational River: The contributing watershed is approximately 3,072 mi^2 in size with roughly 170 miles of streams contained within the park boundary. Of the total river miles within park boundaries, 31 miles designated as “high quality” by the State of Pennsylvania. New York does not have an equivalent designation. Overall, surface waters within the park boundary appear to be of good quality for aquatic health and recreational uses. All portions of the Delaware River mainstem, and the West Branch of the Delaware River located within the park property are listed as impaired on the Pennsylvania human health 303d list. Mercury and PCB pollution are listed as the cause of impairment. These listings are the result of a 1995 study, which found elevated levels of these pollutants in fish tissue. Currently, the state of Pennsylvania has not announced a TMDL assessment date for any sections of the impaired waters within the park. An analysis of 1990-2004 water quality data indicates that pH, fecal coliform and manganese concentrations may be adversely affecting water quality in the park. Currently, there are 4 active water quality monitoring stations and 5 active USGS stream discharge stations within or near the park boundary that could be utilized in a monitoring program.

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for

ALLEGHENY PORTAGE RAILROAD
NATIONAL HISTORIC SITE

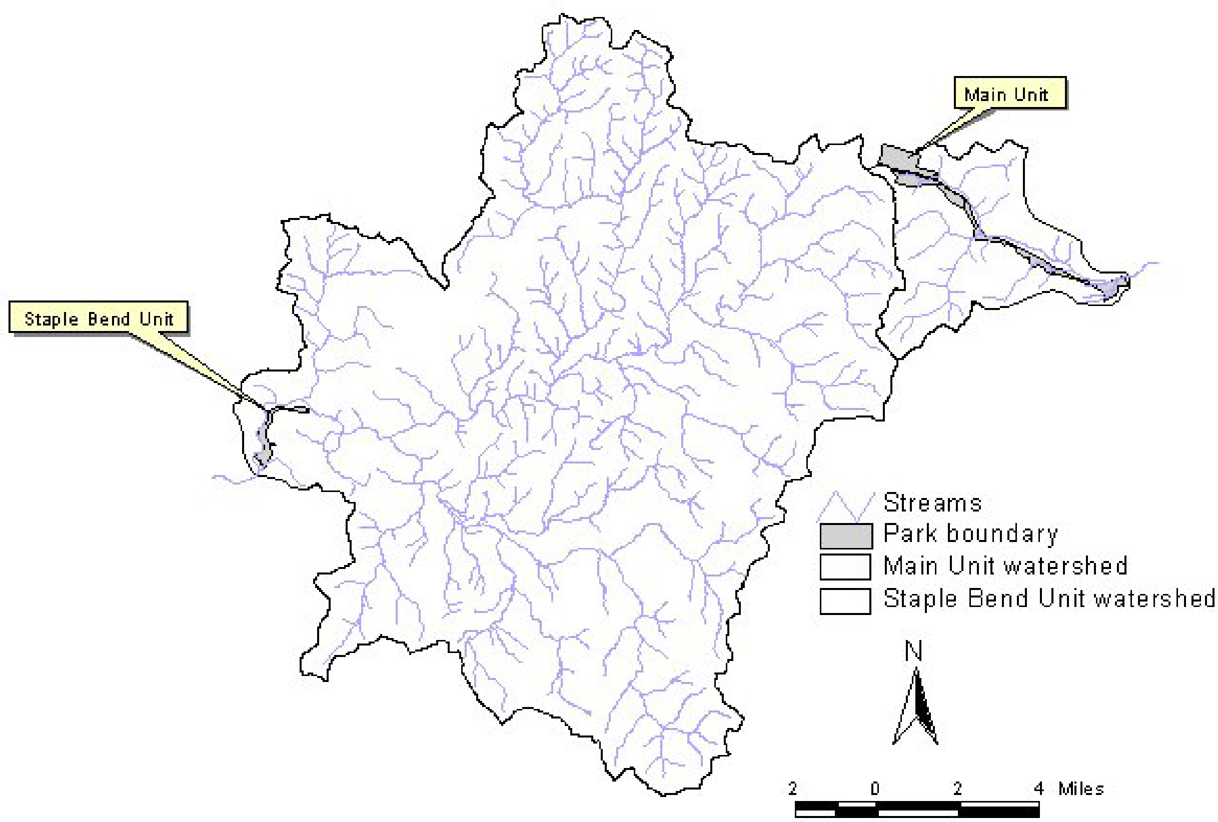
September 2004

Overview of Park/Watershed Characteristics

The Allegheny Portage Railroad National Historic Site (ALPO) is actually comprised of two separate parcels (see Figure 1). The easternmost parcel is referred to as the "Main Unit", and the westernmost parcel is referred to as the "Staple Bend Unit". The entire site is about 1.9 square miles (or 1280 acres) in size, with the Main Unit being the larger of the two.

Both sites are actually contained within two different watersheds. For the purposes of this assessment, the watershed for the Main Unit is defined by the drainage area for the headwater streams that run through or drain this particular site. This area is about 17.4 square miles in size, contains about 32 miles of streams, and is comprised primarily of woodland. The Main Unit is drained primarily by Blair Gap Run and tributaries thereof. (Note that a small portion of this property actually drains via Bradley Run to the Clearfield Creek watershed at the northern end of the park). Although the watershed within which the Staple Bend Unit is located is about 179 square miles in size, this particular site only drains a very small portion of this area (about 1 square mile). Only a very small segment of one stream (a tributary of the Little Conemaugh River) actually runs through NPS property, and the Little Conemaugh River runs along the western edge of the site. There are no gages located on either site. Hence, no flow estimates can be provided for either.

Figure 1. Location of park units and associated watersheds and streams.



Historical Water Quality Overview

Detailed analyses of water quality within and around ALPO, as well as other national parks, has previously been prepared by the Water Resources Division (WRD) of the National Park Service (NPS, 1995). These reports are typically referred to as "Horizon" reports after the contractor that performed most of the analyses (Horizon Systems Corporation). In the case of ALPO, the Horizon report included an analysis of this park as well as one for the Johnstown Flood National Memorial. For these two areas, the analyses described in the Horizon report were collectively done for the period 1926-1997 using data for a total of 381 water quality monitoring stations (both active and inactive) in and around the two parks. It should be noted here, however, that almost all of the stations reported on are located on streams that do not flow through the two park areas, or do not contribute any flow or loads to either park area. Therefore, most of the results presented in the earlier report (and summarized below) may not be relevant with respect to water quality issues facing ALPO.

In the Horizon report, it was noted that during the 1926-1997 period, stream observations for a total of 17 parameters exceeded the screening criteria used in the study at least once within the combined study area boundary used (which as noted above, was larger than the drainage area for the park). These parameters included dissolved oxygen, pH, turbidity, bacteria (total coliform and fecal coliform), total alkalinity, cyanide, sulfate, nitrate, antimony, beryllium, cadmium, copper, lead, nickel, thallium, and zinc. The criteria used for various parameters included EPA criteria for the protection of freshwater aquatic life and drinking water, and WRD screening limits for freshwater bathing. Based on the results of this study, it was believed by the authors that surface waters within the area studied had been impacted by human activities, and that such impacts were primarily due to mining and quarrying activities, municipal and industrial wastewater discharges, agricultural operations, oil and gas development, stormwater runoff, recreational use, and atmospheric deposition. However, given the fact that the assessment was done using some very old monitoring data (i.e., back to 1926 in some cases), it is likely that some of the problems identified have since been rectified (e.g., those related to municipal and industrial discharges), and that other problems related to coal mining have diminished somewhat due to the fact that there are far fewer active mines now than there were during the time period studied.

Many of the contaminant exceedances described above are probably not particularly important today either because of very low exceedance percentages (e.g., 5% of the total observations or less), or because such exceedances occurred over 20 years ago. Based on the above limitations, it appears that the primary parameters of concern now in the areas surrounding both ALPO units are dissolved oxygen, pH, cyanide, sulfate, copper, nickel, and zinc. These concerns are borne out by the fact that many of the surface water bodies in the larger watersheds of which both ALPO units are a part have been included on Pennsylvania's 303d list (as discussed in a later section) for impairments due to mine drainage, urban stormwater runoff, and industrial and municipal point sources.

Specially Designated Surface Water Bodies

There are no specially-designated or otherwise protected streams (e.g., “high quality”) located within either of the two ALPO units. Table 1 provides information on the designated uses of all streams falling within the park boundary, and Table 2 provides descriptions of each of these uses. Figure 2 shows the location of these streams in relation to each park unit.

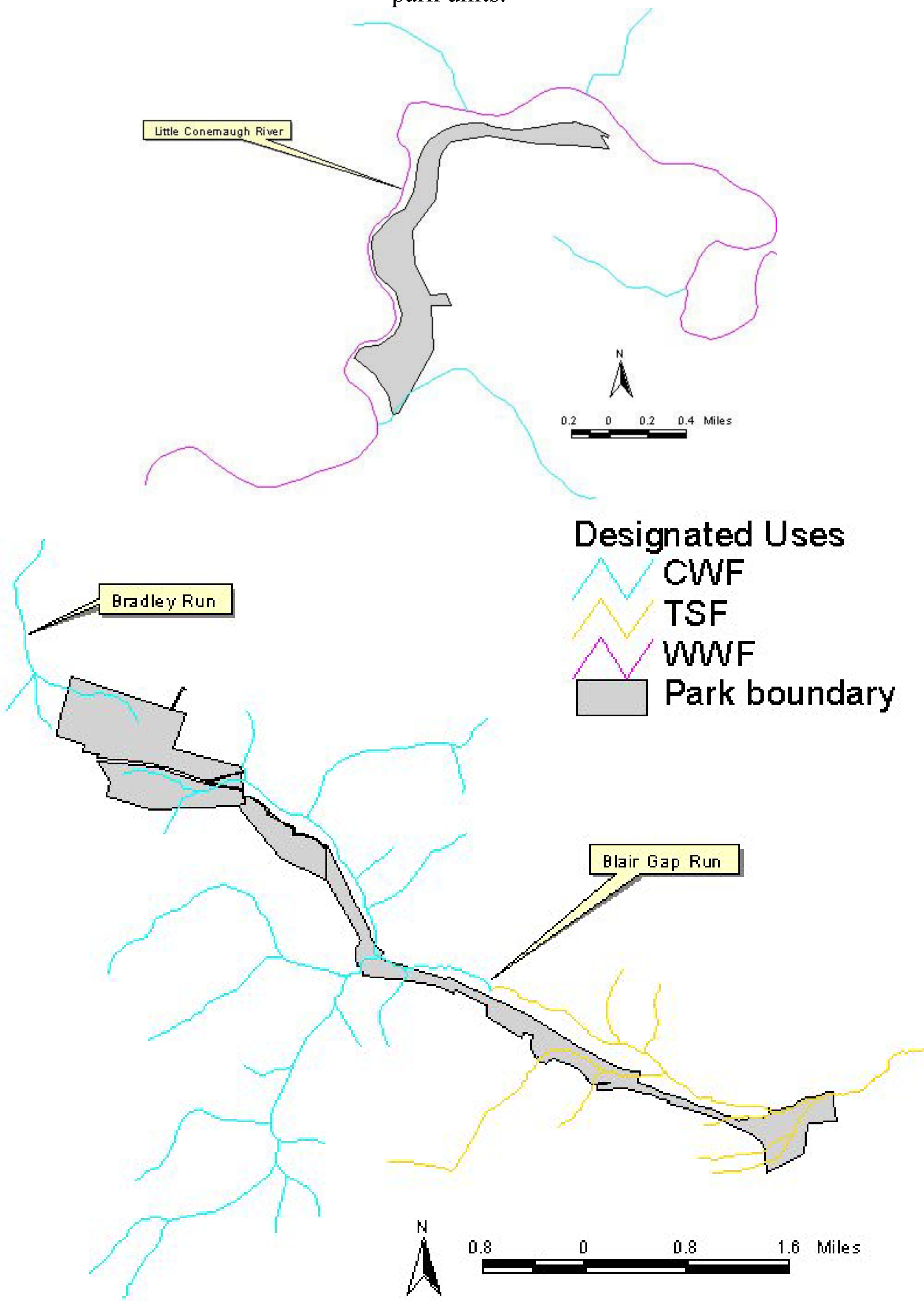
Table 1. Designated uses by stream.

Stream Name	Reach Description	Water Status	Stream Miles	High Quality
Bradley Run	Basin	CWF	0.65	No
Blair Gap Run	Basin: Source to Altoona Reservoir at RM 5.6	CWF	1.91	No
Blair Gap Run	Main Stem: Altoona Reservoir at RM 5.6 to Mouth	TSF	0.54	No
Unnamed Tributary - Blair Gap Run	Basin: Altoona Reservoir at RM5.6 to Mouth	TSF	2.03	No
Unnamed Tributary - Little Conemaugh River	Basin: North Branch Little Conemaugh River to confluence with Stony Creek	CWF	0.13	No

Table 2. Descriptions of designated water uses in Pennsylvania.

Protected Water Uses in Pennsylvania
CWF - *Cold Water Fishes* - Maintenance or propagation, or both, of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat
WWF - *Warm Water Fishes* - Maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat
MF - *Migratory Fishes* - Passage, maintenance and propagation of anadromous and catadromous fishes and other fishes which ascend to flowing waters to complete their life cycle.
TSF - *Trout Stocking* - Maintenance of stocked trout from February 15 to July 31 and maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
HQ - *High Quality Waters* - Surface waters having quality which exceeds levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water by satisfying § 93.4b(a). **EV** - *Exceptional Value Waters* - Surface waters of high quality which satisfy § 93.4b(b) (relating to antidegradation).

Figure 2. Designated uses for streams in the vicinity of the Staple Bend (top) and Main (bottom) park units.



Current Listing of Water Quality Impairments

There are no surface water bodies contained within either unit of the ALPO park that are currently included on Pennsylvania's 303d list of impaired water bodies. There is a problem with acid mine drainage at the Staple bend Unit; however, the drainages within this unit do not qualify as streams eligible for listing because they consist solely of drainage from mine openings and would otherwise not exist.

Current Water Quality Trends

Using more recently-compiled water quality data mean annual concentration values for selected parameters were compared with criteria similar to those used in the earlier Horizon reports to assess whether potential water quality problems identified in the past still exist. These selected parameters were based on various factors, including past problems described in the Horizon report, problems identified in the 303d listings, and the list of core parameters to be used as "vital sign" indicators as identified by NPS WRD. Temperature is also listed as one of the core parameters, but was not included here for several reasons. First, there are no established temperature criteria to use to evaluate the condition of aquatic systems. Secondly, trends in temperature could be evaluated but the results may prove misleading due to natural long-term air temperature trends and the relationship between air and water temperature (i.e. gradual warming of mean annual water temperature may reflect recent warming of the climate, and not watershed disturbance).

Temporal trends for selected water quality parameters were also determined to provide a sense of potential changes in the parameters over time (i.e., are problems getting worse or better?). Temporal trends were evaluated for each constituent that exceeded concentration criteria during the period of analysis (1990-present). To determine the existence of a temporal trend, concentration values were plotted against date and fit with a linear trendline in MS Excel.

Based upon information provided in previous sections, water quality statistics and trends were determined for total nitrogen, total phosphorus, specific conductivity, pH, fecal coliform, cyanide, sulfate, copper, nickel, zinc, mercury, iron, aluminum, manganese, and dissolved oxygen where the appropriate data were available. These parameters were selected because they are commonly used to assess certain aspects of the hydrologic system, and are briefly discussed below. The water quality stations for which data were compiled for this analysis are shown in Figure 3. In all cases, an attempt was made to use any sample data collected from 1990 up to the present. However, as can be seen from Table 3, data from some of these sites were only as recent as 1997. As can also be seen from Table 3, exceedances based on the criteria used only occurred for the parameters pH and specific conductivity.

Specific Conductivity is the ability of a substance to conduct an electrical current across a given length at a specified temperature. Specific Conductivity can be used as an indicator of water quality because pure water has a very low electrical conductance. As concentrations of different ions dissolved in water increase, so does the conductivity. Therefore, conductivity is directly related to the amount of charged particles (i.e. heavy metals, clay particles, etc.) contained within a water sample. While there are no set conductivity criteria for fresh water, specific conductance is linearly related to the concentration of total dissolved solids in a sample. For the purposes of this investigation,

$$0.65*K = S$$

where K is conductance (micromhos) and S is dissolved solids (mg/L). The EPA has a recommended criterion of 500 mg/L for dissolved solids in drinking water (US EPA, 2002a). This corresponds to a specific conductivity of 325 micromhos, given the equation above.

pH is one of the most general indicators of water quality. The natural logarithm of hydrogen ion concentration in solution, pH ranges from 0-14 with 7 being neutral. pH values ranging from approximately 6-8 naturally occur in freshwater aquatic systems. The EPA-established criterion for aquatic life protection includes pH values between 6.5 and 9.0. For the purposes of this investigation, recorded values outside of this range were flagged as an indication of impairment.

Fecal Coliform bacteria levels were used as an indicator of failing sewage treatment facilities or otherwise untreated wastewater upstream of a sampling point. In discussion of indicator bacteria, it should be noted that the EPA recommends the analysis of either E. Coli or enterococci bacteria for this purpose. However, there are very few samples of E. Coli and enterococci bacteria available for assessment of aquatic ecosystem health. Therefore, Fecal Coliform data were examined using an EPA (2002b) established threshold of 200 colony forming units (CFU).

High loads and or concentrations of *Total Nitrogen, Total Phosphorus, and Total Suspended Sediment* are often correlated with excessive fertilization of agricultural land, ineffective agricultural management strategies, high levels of impervious surface area, and other anthropogenic disturbances within the watershed. No nationally recognized criteria exist for these three parameters, so criteria published by Sheeder and Evans (2004) were employed. The criteria were developed for the state of Pennsylvania, and are though to be relatively accurate for regions of New York and West Virginia as well. The criteria for total nitrogen, total phosphorus, and total suspended sediment are 2.01 mg/L, 0.07 mg/L, and 197.27 mg/L respectively.

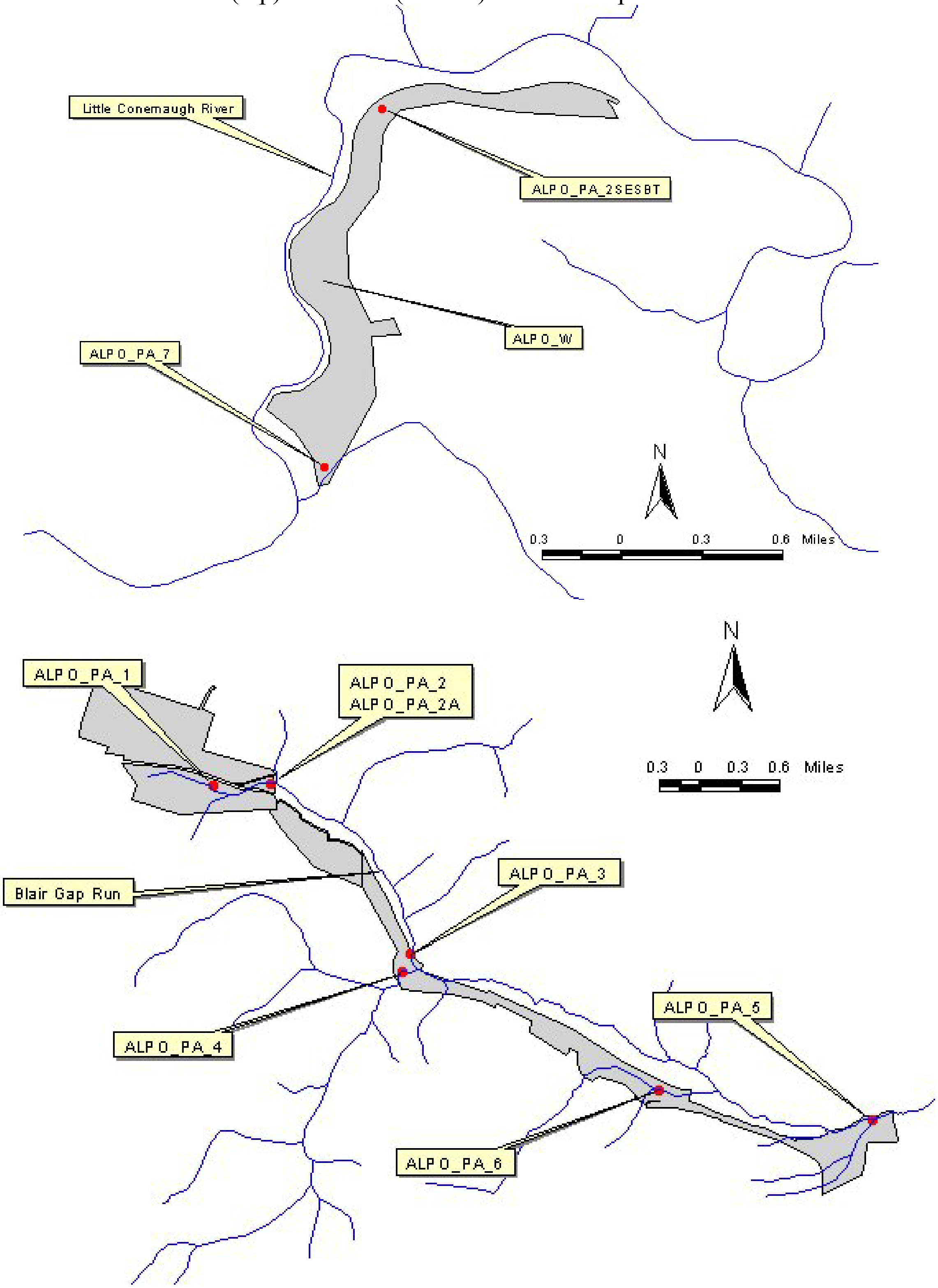
Elevated concentrations of *Mercury, Iron, Aluminum, and Manganese* and many other metals are commonly associated with large-scale disturbances within a watershed including mining and large-scale construction projects. Elevated metals concentrations can also result from acidic deposition, low watershed acid buffering capacity, and other factors. These four metals were selected from the larger suite of metals associated with mining/disturbance impairments because each has been explicitly implicated as the cause of impairment in section 303d-listed watersheds in Pennsylvania, West Virginia, New York and/or New Jersey. The EPA has published criterion for each of the metals analyzed in this report (USEPA, 2002c). Mercury is designated as a priority pollutant, and has a freshwater CMC criterion of 1.4 ug/l. Iron, Aluminum and Manganese are listed as non-priority pollutants. Iron and Aluminum are assigned freshwater criteria of 1000 ug/L (CCC) and 750 ug/L (CMC) respectively. There is no freshwater criterion set for Manganese. In the absence of an aquatic health criterion, the EPA human health consumption criterion of 50 ug/L was used to define exceedances.

Table 3. Results of analyses based on recently-compiled water quality data at stations in and around the Allegheny Portage Railroad National Historic Site.

Station ID	Station Name	Chemical Characteristic	Exceedances	No. Obs.	% Exceed	Begin Date	End Date	Min. Value	Max. Value	Avg. Value
ALPO_PA_1	Blair Gap Run across Route 22 from Lemon House	pH (standard units)	4	5	80 %	May-96	Jun-97	4.88	6.83	6.00
		Specific Conductance	2	2	100 %	Mar-97	Jun-97	350	432	391
ALPO_PA_2	Blair Gap Run Below Skew Arch Bridge	pH (standard units)	2	4	50 %	May-96	Jun-97	6.38	7.05	6.62
		Specific Conductance	1	2	50 %	Mar-97	Jun-97	243	338	291
ALPO_PA_2A	Culvert on Blair Gap Run below Skew Arch Bridge	pH (standard units)	1	1	100 %	Mar-97	Mar-97	6.47	6.47	6.47
		Specific Conductance	1	1	100 %	Mar-97	Mar-97	383	383	383
ALPO_PA_2SESBT	Second stream east of Staple Bend Tunnel	pH (standard units)	1	1	100 %	May-96	May-96	3.79	3.79	3.79
ALPO_PA_3	Blair Gap Run downstream of Muleshoe Bridge	pH (standard units)	2	5	40 %	May-96	Jun-97	6.29	7.04	6.66
ALPO_PA_4	Adams/Blair Run below Muleshoe Reservoir	pH (standard units)	4	5	80 %	May-96	Jun-97	5.83	6.62	6.23
ALPO_PA_5	Tributary below Foot of Ten	pH (standard units)	3	3	100 %	May-96	Mar-97	6.18	6.48	6.35
ALPO_PA_6	Picnic area above Foot of Ten	pH (standard units)	4	4	100 %	May-96	Jun-97	5.98	6.41	6.13
ALPO_PA_7	Stream west of Staple Bend Tunnel	pH (standard units)	2	2	100 %	May-96	May-96	6.18	6.48	6.33

Notes: "Exceedances" refers to the number of times observed values exceeded the threshold criteria used for any given parameter.

Figure 3. Locations of water quality stations used in analysis of recent trends for the Staple Bend (top) and Main (bottom) units of the park.



Dissolved Oxygen concentration is the final parameter selected for analysis in this report. Dissolved oxygen concentrations above designated thresholds are essential for the survival of aquatic vertebrates and invertebrates, while low values suggest nuisance algae populations stemming from nutrient pollution. Several different criteria have been specified, due to the varying tolerances of adult and juvenile, warm water and cold water species. For the purposes of this investigation, the one-day minimum, coldwater fishery criterion of 4 mg/L (USEPA, 1986) is employed. This criterion is thought to be the most appropriate because the limit will include all warm water violations, without including samples that would be flagged using the coldwater, juvenile fish criteria (juvenile fish are prevalent during the spring, when mechanical saturation provides sufficient oxygen levels in all but the most impaired watersheds. These watersheds will be identified using the one-day minimum coldwater fishery criteria or via one of the other chemicals).

From the results in Table 3, it can be seen that pH due to mine drainage may still be an issue in both units of the park, even though no streams within the park have been included on Pennsylvania's 303d list. Some of the pH values measured, however, were very close to the criteria of 6.5 used for the purposes of this analysis. As discussed in a later section, new water quality samples are currently being obtained to assess the existence and extent of potential problems in the eastern portion of the park.

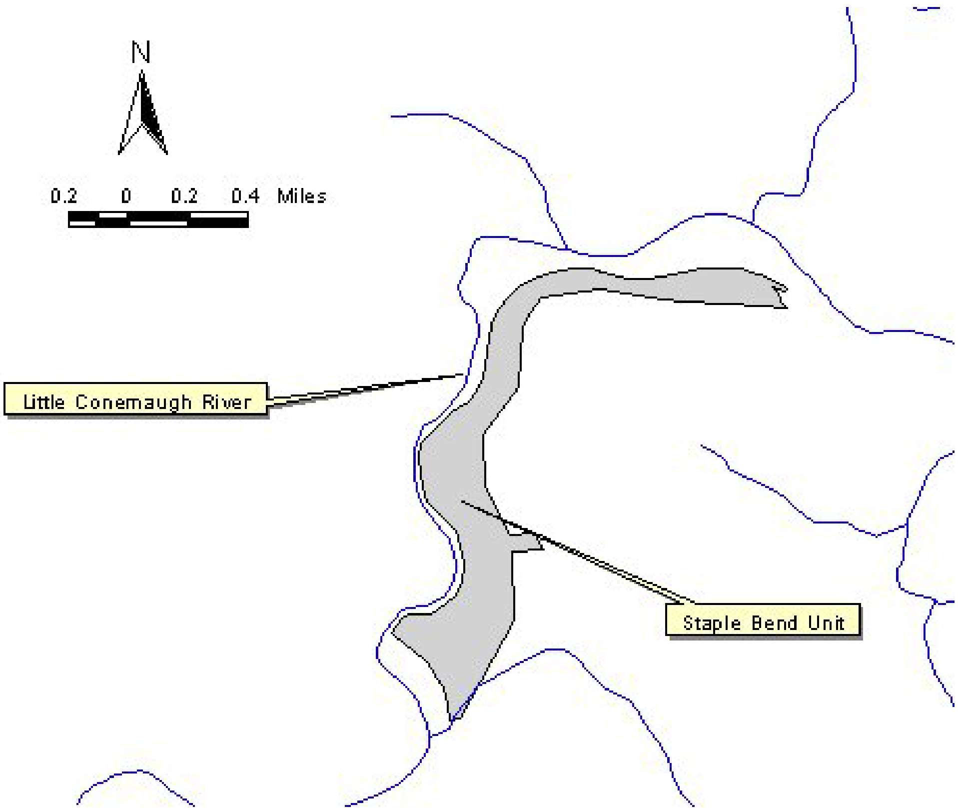
TMDL Development

The Pennsylvania Department of Environment Protection (DEP) is the agency responsible for conducting total maximum daily load (TMDL) assessments for impaired waters in the Commonwealth of Pennsylvania. A TMDL is essentially a plan of action used to clean up streams that are not meeting water quality standards. The plan includes pollution source identification and strategy development for contaminant source reduction or elimination. As of the date of this document (September 2004), no water bodies within the ALPO park boundary have been identified as requiring a TMDL. However, various reaches of the Little Conemaugh River (see Figure 4) that abuts the western edge of the Staple Bend Unit have been listed for pH and metals impairments due to abandoned mine drainage. These stream segments are scheduled to have TMDLs completed for them by either 2009 or 2015, depending upon the specific location.

Presence of Water Quality Monitoring Sites

At present, there are no long-term water quality monitoring stations located in or near the park. However, as part of an ongoing "Level 1" monitoring project being completed for the National Park Service, Penn State University is collecting water quality data at various locations within the Main Unit. More specifically, samples are being taken at 6 different locations along Blair Gap Run that flows through this unit. Data being collected include in-stream measurements of alkalinity, pH, specific conductivity, dissolved oxygen, temperature, instantaneous stream discharge, selected toxics (e.g., cyanide and mercury), nutrients (N and P), turbidity, and fecal coliform.

Figure 4. Location of Little Conemaugh River with respect to the Staple Bend Unit.



Recommendations for Future Monitoring

Based on the analyses of sample data from the mid-1990s, it appears that there are still some problems related to mine drainage in both units of the park, although no streams within the park have been included on Pennsylvania's 303d list. To determine the location and magnitude of such problems, water quality is currently being monitored at several locations in the main unit of the park as described earlier. Additional monitoring data collection in this unit may or may not be needed depending upon the outcome of this work. No additional monitoring is recommended in the Staple Bend Unit, as work is currently being done by the National Park Service to remediate mine drainage problems in this particular area.

Literature Cited

National Park Service. 1999. Baseline Water Quality Data Inventory and Analysis: Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial, Tech. Report NPS/NRWRD/NRTR-99/205, 1193 pp.

Sheeder, S. A. and B.M. Evans, 2004. Estimating Nutrient and Sediment Threshold Criteria for Biological Impairment in Pennsylvania Watersheds. Journal of the American Water Resources Association (JAWRA) 40(4): 881-888.

USEPA (U.S. Environmental Protection Agency), 2002a. List of Drinking Water Contaminants & MCLs. EPA 816-F-02-013, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2002b. Implementation Guidance for Ambient Water Quality Criteria for Bacteria. EPA-823-B-02-003, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2002c. National Recommended Water Quality Criteria: 2002. EPA-822-R-02-047, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 1986. Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003, U.S. Environmental Protection Agency, Washington, D.C.

WATER QUALITY SUMMARY

for

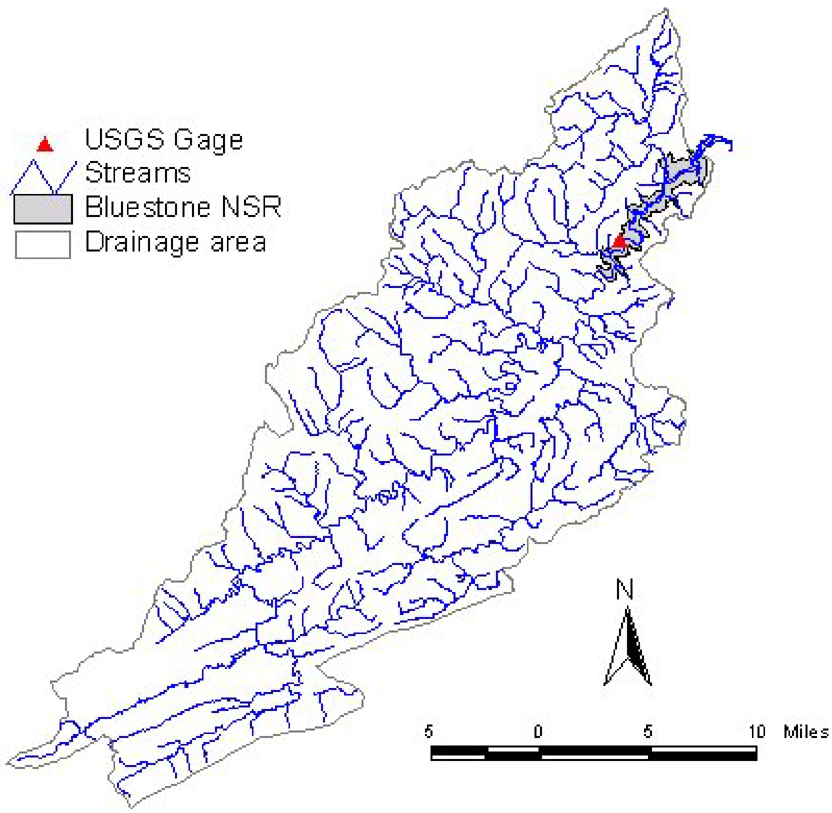
BLUESTONE NATIONAL SCENIC RIVER

September 2004

Overview of Park/Watershed Characteristics

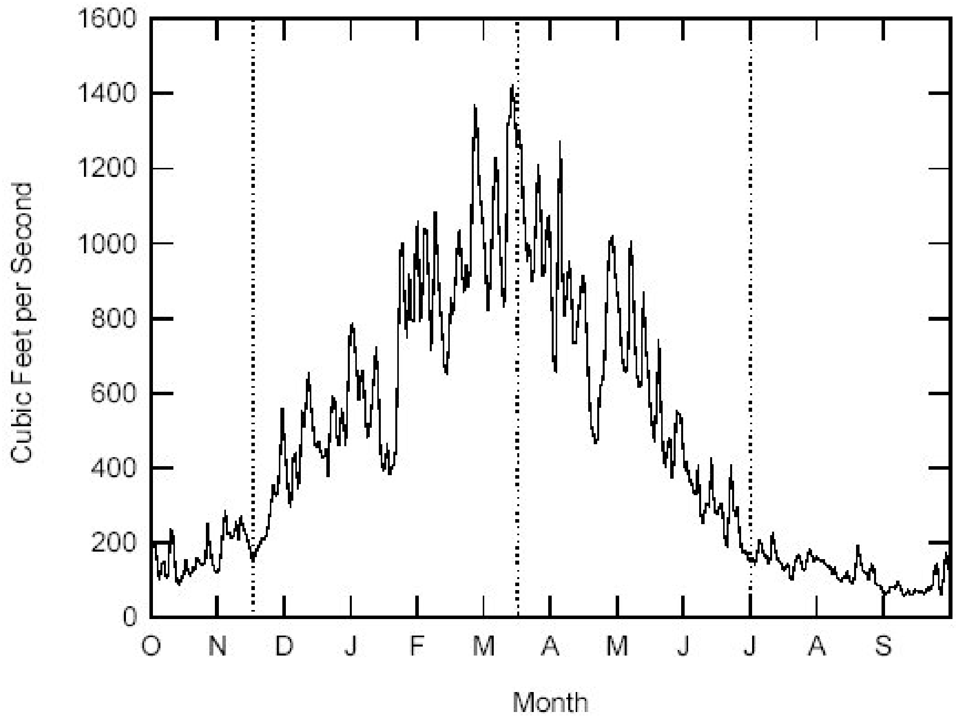
The park is approximately 4,336 acres (6.8 mi^2) in size, and is comprised almost entirely of woodland. The drainage area within which the park is located is approximately 276,914 acres (433 mi^2) in size (see Figure 1). The land use/cover within this watershed is predominantly woodland, with about 20% of the area being covered by crop and pasture land. One mid-size town (Princeton) is located to the southwest of the park. There are also small pockets of mined land located in the western and southern portions of the watershed.

Figure 1. Location of park, watershed and USGS gages.



As measured at the USGS gage (3179000) at the upper end of the park, the mean daily stream flow on an annual basis within the Bluestone River is about 463 cfs. Temporal variations in flow on a mean annual basis are depicted in Figure 2.

Figure 2. Representative mean annual hydrograph of flows by month for the Bluestone River as derived for a 38-year period (from Bluestone NSR Horizon report).



Historical Water Quality Overview

Detailed analyses of water quality within and around the Bluestone NSR, as well as other national parks, has previously been prepared by the Water Resources Division (WRD) of the National Park Service (NPS, 1995). These reports are typically referred to as "Horizon" reports after the contractor that performed most of the analyses (Horizon Systems Corporation). For the Bluestone NSR, a Horizon report was done for the period 1946-1995 using data for 29 water quality monitoring stations (both active and inactive) in and around the park. It should be noted here, however, that only 19 of the stations reported on are located on streams that either flow through the park or contribute any flow or loads to the watershed within which the park is located. Therefore, some of the results presented in the earlier report (and summarized below) may not be relevant with respect to water quality issues facing the park.

In the Horizon report, it was noted that during the 1946-1995 period, stream observations for a total of 17 parameters exceeded the screening criteria used in the study at least once within the study area boundary used (which as noted above, included stations outside of the drainage area for the park). These parameters included dissolved oxygen, pH, antimony, cadmium, chromium, copper, lead, mercury, silver, zinc, cyanide, sulfate, beryllium, chloride, nickel, thallium, bacteria (total coliform and fecal coliform), and turbidity. The criteria used for various parameters included EPA criteria for the protection of freshwater aquatic life and drinking water, and WRD screening limits for freshwater bathing. Based on the results of this study, it was believed by the authors that surface waters within the area studied had been impacted by bacteria and trace metals, and that potential sources of these impacts included municipal and residential development, recreational uses, farming and livestock grazing, and abandoned and active coal mines. However, given the fact that the assessment was done using some very old monitoring data (i.e., back to 1946 in the cases of pH and DO), it is likely that some of the problems identified have since been rectified (e.g., those related to municipal discharges), and that other problems related to coal mining have diminished somewhat due to the fact that there are far fewer active mines now than there were during the time period studied.

Many of the contaminant exceedances described above are probably not particularly important today either because of very low exceedance percentages (e.g., 5% of the total observations or less), or because such exceedances occurred over 20 years ago. Based on the above limitations, it appears that the primary pollutants of concern now (particularly in the Bluestone River) are bacteria (total coliform and fecal coliform), and mine-related contaminants such as lead, mercury, and zinc. These concerns are borne out by the fact that a number of the surface water bodies in the Bluestone River watershed have been included on West Virginia's 303d list (as discussed in a later section) for impairments due to fecal coliform, or because of biological impairments due to "unknown" causes.

Specially Designated Surface Water Bodies

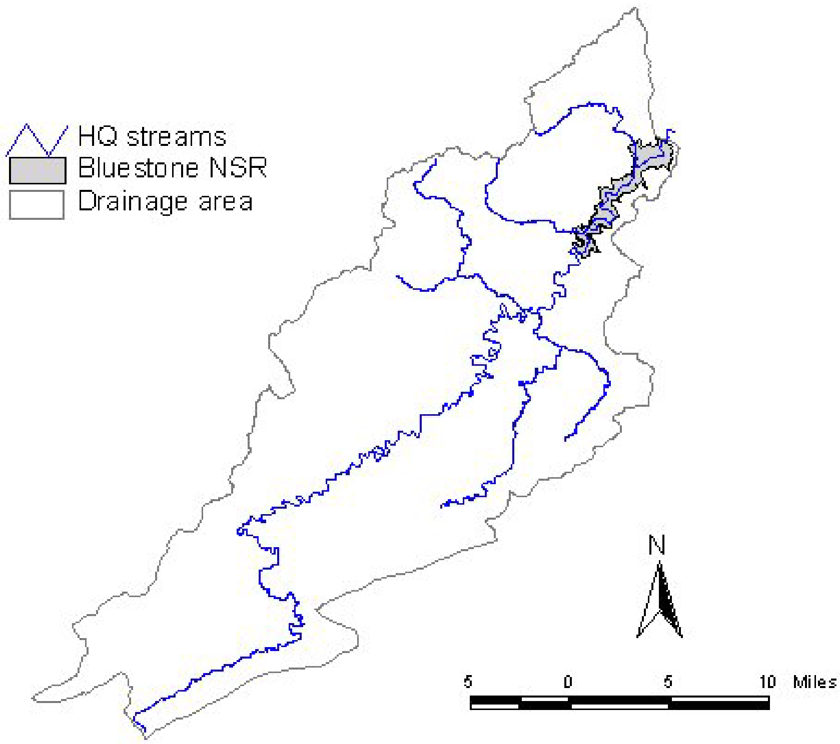
There are approximately 598 miles of streams depicted in the watershed in Figure 1 that serves as the drainage area for the Bluestone NSR. Of this total, approximately 150 miles have been designated as "high quality" streams (see Figure 3). Of the approximately 17.7 miles of streams contained with the park boundary, about 12.4 miles have been designated as being "high quality", including the Bluestone River, Little Bluestone River, and Mountain Creek (see Figure 4). Table 1 provides information on the status of all streams falling within the park boundary in terms of meeting their designated uses, and Table 2 provides descriptions of each of these uses.

As defined by the State of West Virginia, "high quality waters" are those waters whose quality is equal to or better than the minimum levels necessary to achieve the national water quality goal uses. Such waters require what is defined as "Tier 2" protection, which requires that the existing high quality waters of the state must be maintained at their existing high quality unless it is determined after satisfaction of the intergovernmental coordination of the state's continuing planning process and opportunity for public comment and hearing that allowing lower water quality is necessary to accommodate important economic or social development in the area in which the waters are located. If limited degradation is allowed, it shall not result in injury or interference with existing stream water uses or in violation of state or federal water quality criteria that describe the base levels necessary to sustain the national water quality goal uses of protection and propagation of fish, shellfish and wildlife and recreating in and on the water.

High quality waters may include but are not limited to the following:

- Streams designated by the West Virginia Legislature under the West Virginia Natural Stream Preservation Act, pursuant to W. Va. Code §22-13-5;
- Streams listed in West Virginia High Quality Streams, Fifth Edition, prepared by the Wildlife Resources Division, Department of Natural Resources (1986); and
- Streams or stream segments which receive annual stockings of trout but which do not support year-round trout populations.

Figure 3. Location of high quality streams in the entire watershed.



Current Listing of Water Quality Impairments

As shown in Figure 5, a number of surface water bodies within the drainage area of the Bluestone NSR have been identified as being impaired on West Virginia's 303d list. As can also be seen from Figure 4, many of these same streams have also been designated as "high quality" streams. Most of the impaired surface waters in the larger watershed are listed for problems related to fecal coliform, or being biologically impaired due to "unknown" causes; although Rich Creek has been listed due to problems related to mine drainage. Table 3 provides information on the impaired surface water bodies either in or immediately adjacent to the Bluestone NSR, and Figure 6 depicts the location of these streams. Within the park, about 12.7 miles of stream have been listed as being impaired. As can be seen from Figures 4 and 6, those streams designated as being "high quality" are essentially the same stream segments listed as being water quality-impaired by the West Virginia DEP.

Figure 4. Location of designated “high quality” streams within the park boundary.

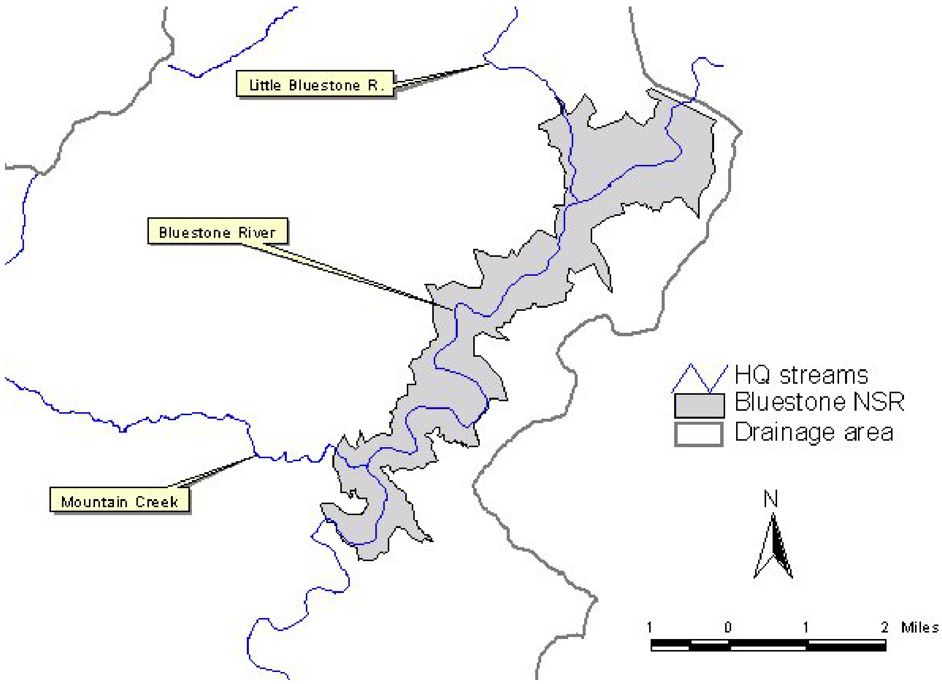


Figure 5. Location of impaired surface water bodies on 303d list.

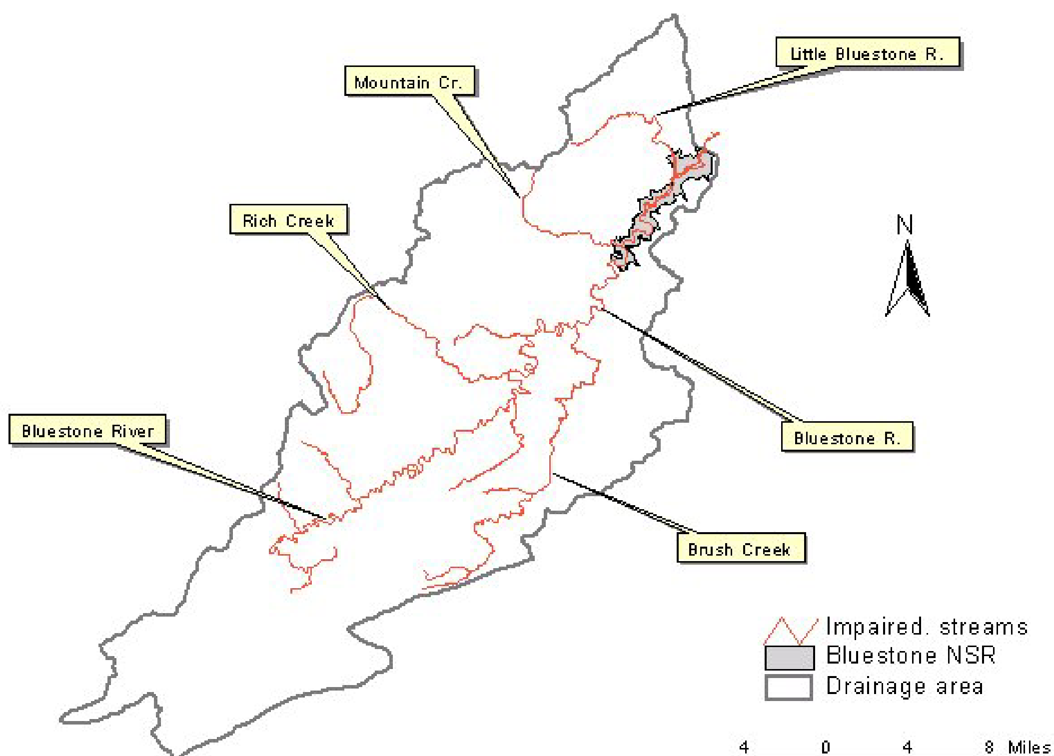


Table 1. Status of designated uses of streams within the park boundary.

Stream	Stream Miles or Lake Size	Category	Agricultural and Wildlife Uses	Public Water Supply	Trout Waters	Warm Water Fishery Streams	Water Contact Recreation	High Quality
Bluestone River	10.96	5	Fully Supporting	Not Supporting	N/A	Fully Supporting	Not Supporting	Yes
Little Bluestone River	1.42	5	Fully Supporting	Not Supporting	Fully Supporting	N/A	Not Supporting	Yes
Tony Hollow	0.03	3	Not Assessed	Not Supporting	N/A	Not Assessed	Not Assessed	No
Mountain Creek	0.50	5	Fully Supporting	Not Supporting	N/A	Insufficient Information	Not Supporting	Yes

Table 2. Various “use-related” descriptions for streams used in West Virginia.

West Virginia 305b Category Descriptions

Category 1: Fully Supporting all designated uses.
Category 2: Fully supporting some designated uses, but no or insufficient information exists to assess the other designated uses.
Category 3: Insufficient or no information exists to determine if any of the uses are being met.
Category 4a: Waters that already have an approved TMDL but are still not meeting standards.
Category 5: Waters that have been assessed as impaired and are expected to need a TMDL.

West Virginia Use Attainment Descriptions

Fully Supporting: The sampled data suggest that stream can attain the designated use.
Insufficient Information: Some data suggest that stream may or may not attain the designated use. Not enough samples to conclude whether or not the stream can attain the designated use.
Not Supporting: The sample data suggest that stream cannot attain the designated use.
Not Assessed: No data have been collected.
N/A: No assessment information provided.

West Virginia Special Waters Designated Use Descriptions

Public Water Supply: This category is used to describe waters which, after conventional treatment, are used for human consumption. This category includes streams on which the following are located:

a) All community domestic water supply systems;
b) All non-community domestic water supply systems (i.e., hospitals, schools, etc.);
c) All private domestic water systems;
d) All other surface water intakes where the water is used for human consumption. The manganese human health criteria shall not apply where the discharge point of the manganese is located more than five miles upstream from a known drinking water source.

Agricultural and Wildlife Uses:

a) Irrigation – This category includes all stream segments used for irrigation.
b) Livestock watering – This category includes all stream segments used for livestock watering.
c) Wildlife – This category includes all stream segments and wetlands used by wildlife.

Water Contact Recreation: This category includes swimming, fishing, water skiing and certain types of pleasure boating such as sailing in very small craft and outboard motor boats.

Warm Water Fishery Streams: Streams or stream segments which contain populations composed of all warm water aquatic life.

Trout Waters: Streams or stream segments which sustain year-round trout populations. Excluded are those streams or stream segments which receive annual stockings of trout but which do not support year-round trout populations.

High Quality Waters: Waters whose quality is equal to or better than the minimum levels necessary to achieve the national water quality goal uses.

Figure 6. Location of impaired streams within the park boundary.

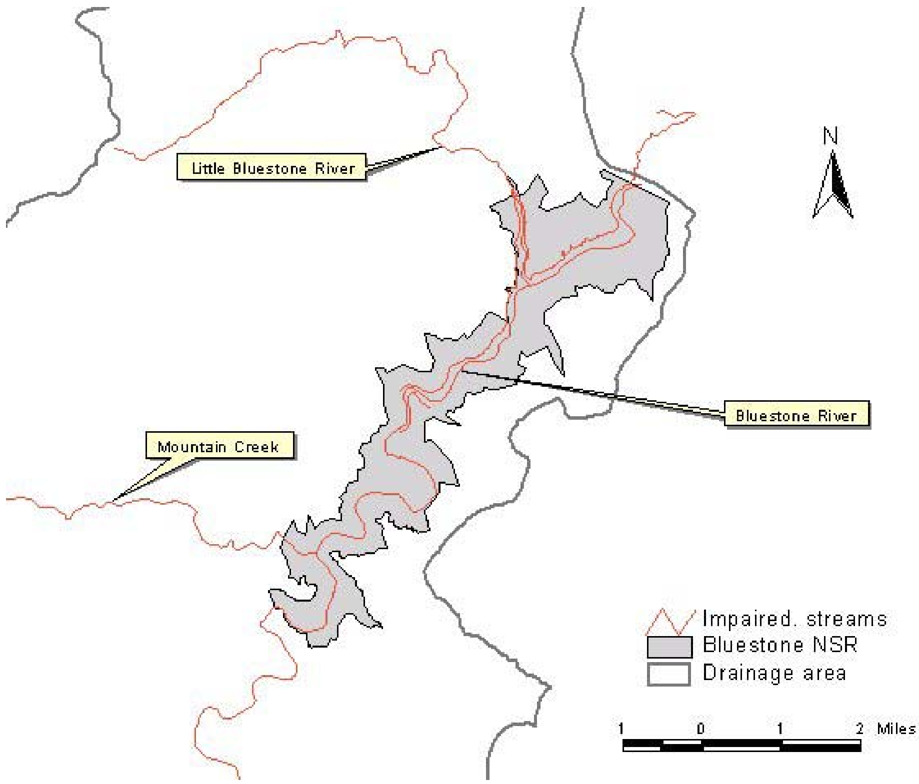


Table 3. Sources and causes of listed impairments.

Surface Water Body	Cause	Source	On 2002 List?
Bluestone River	Fecal coliform	Unknown	Yes
Little Bluestone R.	Fecal coliform	Unknown	No
Mountain Creek	Fecal coliform	Unknown	No

According to the Horizon report, there are two relatively small industrial dischargers located upstream of the park (permit numbers WV0035424 and WV0089851). The first is a small "tourism-related" facility, and the second is "utility-related". Given the fact that streams in the park have been 303d-listed for fecal coliform impairments, it is doubtful that either of these facilities are significant in terms of their potential effect on stream water quality within the park.

Current Water Quality Trends

Using more recently-compiled water quality data, mean annual concentration values for selected parameters were compared with criteria similar to those used in the earlier Horizon reports to assess whether potential water quality problems identified in the past still exist. These selected parameters were based on various factors, including past problems described in the Horizon report, problems identified in the 303d listings, and the list of core parameters to be used as “vital sign” indicators as identified by WRD. Temperature is also listed as one of the core parameters, but was not included here for several reasons. First, there are no established temperature criteria to use to evaluate the condition of the aquatic system. Secondly, trends in temperature could be evaluated, but the results may prove misleading due to natural long-term air temperature trends and the relationship between air and water temperature (i.e., gradual warming of mean annual water temperature may reflect recent warming of the climate, and not watershed disturbance).

Temporal trends for selected water quality parameters were also determined to provide a sense of potential changes in such parameters over time (i.e., are problems getting worse or better?). Temporal trends were evaluated for each constituent that exceeded concentration criteria during the period of analysis (1990-present). To determine the existence of a temporal trend, concentration values were plotted against date and fit with a linear trendline in MS Excel. Additionally, loading rates for various water quality parameters were estimated for the entire park drainage area and another sub-area to provide another measure of potential water quality problems.

Based upon information provided in previous sections, water quality statistics and trends were determined for specific conductance, pH, fecal coliform, aluminum, total phosphorus, and dissolved oxygen where the appropriate data were available (see Table 4). These parameters were selected because they are commonly used to assess certain aspects of the hydrologic system, and are briefly discussed below. The water quality stations for which data were compiled for this analysis are shown in Figure 7. In all cases, an attempt was made to use any sample data collected from 1990 up to the present. However, as can be seen from Table 4, data from all of these sites were very limited. In most cases the data were only as current as 1995. In three cases where the data were more current (i.e., the “KNB” stations), only one sample was taken for each station in August of 1999. At another station (551002), the data were only collected for a period of 1 year between 10/90 and 9/91.

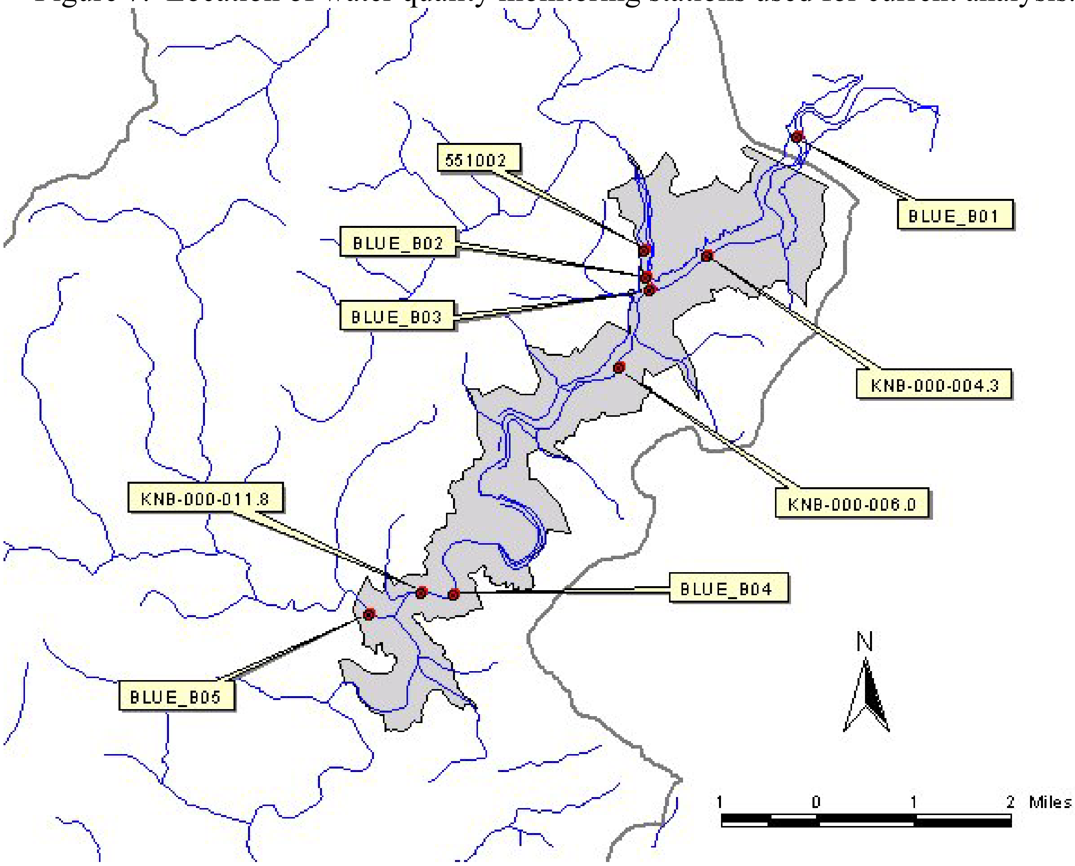
Specific Conductivity is the ability of a substance to conduct an electrical current across a given length at a specified temperature. Specific Conductivity can be used as an indicator of water quality because pure water has a very low electrical conductance. As concentrations of different ions dissolved in water increase, so does the conductivity. Therefore, conductivity is directly related to the amount of charged particles (i.e. heavy metals, clay particles, etc.) contained within a water sample. While there are no set conductivity criteria for fresh water, specific conductance is linearly related to the concentration of total dissolved solids in a sample. For the purposes of this investigation,

$$0.65*K = S$$

where K is conductance (micromhos) and S is dissolved solids (mg/L). The EPA has a recommended criterion of 500 mg/L for dissolved solids in drinking water (US EPA, 2002a). This corresponds to a specific conductivity of 325 micromhos, given the equation above.

pH is one of the most general indicators of water quality. The natural logarithm of hydrogen ion concentration in solution, pH ranges from 0-14 with 7 being neutral. pH values ranging from approximately 6-8 naturally occur in freshwater aquatic systems. The EPA-established criterion for aquatic life protection includes pH values between 6.5 and 9.0. For the purposes of this investigation, recorded values outside of this range were flagged as an indication of impairment.

Figure 7. Location of water quality monitoring stations used for current analysis.



Fecal Coliform bacteria levels were used as an indicator of failing sewage treatment facilities or otherwise untreated wastewater upstream of a sampling point. In discussion of indicator bacteria, it should be noted that the EPA recommends the analysis of either E. Coli or enterococci bacteria for this purpose. However, there are very few samples of E. Coli and enterococci bacteria available for assessment of aquatic ecosystem health. Therefore, Fecal Coliform data were examined using an EPA established threshold of 200 colony forming units (CFU).

Table 4. Results of analyses based on recently-compiled water quality data at stations in and around Bluestone NSR.

Chemical Characteristic	Station ID	Station Name	Exceedances	No. Obs.	% Exceed	Begin Date	End Date	Min. Value	Max. Value	Avg. Value	Trend
ALUMINUM, TOTAL (UG/L AS AL)	551002	Little Bluestone R., Bluestone Fish. & Hunting	1	12	8	Oct-90	Sep-91	50.0	840.0	254.6	NA
PHOSPHORUS, TOTAL (MG/L AS P)	551002	Little Bluestone R., Bluestone Fish. & Hunting	1	12	8	Oct-90	Sep-91	0.004	0.085	0.0	
FECAL COLIFORM,MEMBR FILTER	BLUE_B01	BLUESTONE RIVER AT STATE PARK	8	44	18	May-91	Jun-95	5.0	3400.0	227.4	+
PH, LAB, STANDARD UNITS	BLUE_B01	BLUESTONE RIVER AT STATE PARK	1	51	2	May-91	Jun-95	6.5	9.1	8.1	NA
SPECIFIC CONDUCTANCE	BLUE_B01	BLUESTONE RIVER AT STATE PARK	7	48	15	Jun-91	Jun-95	83.0	365.0	237.2	-
FECAL COLIFORM,MEMBR FILTER	BLUE_B02	LITTLE BLUESTONE RIVER	9	44	20	May-91	Jun-95	3.0	1400.0	180.7	+
OXYGEN, DISSOLVED (MG/L)	BLUE_B02	LITTLE BLUESTONE RIVER	1	44	2	May-91	Jun-95	3.0	13.3	8.9	NA
PH, LAB, STANDARD UNITS	BLUE_B02	LITTLE BLUESTONE RIVER	3	50	6	May-91	Jun-95	6.4	9.9	7.5	NA
FECAL COLIFORM,MEMBR FILTER	BLUE_B03	BLUESTONE RIVER AT CONFLUENCE	3	43	7	May-91	Jun-95	2.1	3580.0	181.6	NA
OXYGEN, DISSOLVED (MG/L)	BLUE_B03	BLUESTONE RIVER AT CONFLUENCE	1	42	2	Jun-91	Jun-95	1.2	13.5	8.1	NA
SPECIFIC CONDUCTANCE	BLUE_B03	BLUESTONE RIVER AT CONFLUENCE	7	47	15	Jun-91	Jun-95	101.0	380.0	249.4	-
FECAL COLIFORM,MEMBR FILTER	BLUE_B04	BLUESTONE RIVER AT PIPESTEM	3	42	7	May-91	Jun-95	6.0	4325.0	166.7	NA
OXYGEN, DISSOLVED (MG/L)	BLUE_B04	BLUESTONE RIVER AT PIPESTEM	2	42	5	May-91	Jun-95	1.0	14.2	9.6	NA
PH, LAB, STANDARD UNITS	BLUE_B04	BLUESTONE RIVER AT PIPESTEM	4	50	8	May-91	Jun-95	6.9	10.1	8.4	NA
SPECIFIC CONDUCTANCE	BLUE_B04	BLUESTONE RIVER AT PIPESTEM	9	46	20	Jun-91	Jun-95	90.0	390.0	256.1	-
FECAL COLIFORM,MEMBR FILTER	BLUE_B05	MOUNTAIN CREEK	4	31	13	Apr-92	Jun-95	1.0	1310.0	127.2	+
PH, LAB, STANDARD UNITS	BLUE_B05	MOUNTAIN CREEK	3	38	8	Apr-92	Jun-95	6.2	10.8	7.5	NA
SPECIFIC CONDUCTANCE	BLUE_B05	MOUNTAIN CREEK	3	37	8	Apr-92	Jun-95	50.0	370.0	155.8	NA
SPECIFIC CONDUCTANCE	KNB-000-004.3	Bluestone River east of Ellison, W.Va.	1	1	100	Aug-99	Aug-99	381	381	381.0	NA
SPECIFIC CONDUCTANCE	KNB-000-006.0	Bluestone River southeast of Ellison, W.Va.	1	1	100	Aug-99	Aug-99	388	388	388.0	NA
SPECIFIC CONDUCTANCE	KNB-000-011.8	Bluestone River in Pipestem Resort State Park	1	1	100	Aug-99	Aug-99	371	371	371.0	NA

Notes: 1) “Exceedances” refers to the number of times observed values exceeded the threshold criteria used for any given parameter.
2) For “Trend”, “+” indicates an upward trend in observed concentrations or counts, “-“ indicates a downward trend, and “NA” indicates no obvious trend.

High loads and or concentrations of *Total Nitrogen, Total Phosphorus, and Total Suspended Sediment* are often correlated with excessive fertilization of agricultural land, ineffective agricultural management strategies, high levels of impervious surface area, and other anthropogenic disturbances within the watershed. No nationally recognized criteria exist for these three parameters, so criteria published by Sheeder and Evans (2004) were employed. The criteria were developed for the state of Pennsylvania, and are though to be relatively accurate for regions of New York and West Virginia as well. The criteria for total nitrogen, total phosphorus, and total suspended sediment are 2.01 mg/L, 0.07 mg/L, and 197.27 mg/L respectively.

Elevated concentrations of *Mercury, Iron, Aluminum, and Manganese* and many other metals are commonly associated with large-scale disturbances within a watershed including mining and large-scale construction projects. Elevated metals concentrations can also result from acidic deposition, low watershed acid buffering capacity, and other factors. These four metals were selected from the larger suite of metals associated with mining/disturbance impairments because each has been explicitly implicated as the cause of impairment in section 303d-listed watersheds in Pennsylvania, West Virginia, New York and/or New Jersey. The EPA has published criterion for each of the metals analyzed in this report (USEPA, 2002c). Mercury is designated as a priority pollutant, and has a freshwater CMC criterion of 1.4 ug/l. Iron, Aluminum and Manganese are listed as non-priority pollutants. Iron and Aluminum are assigned freshwater criteria of 1000 ug/L (CCC) and 750 ug/L (CMC) respectively. There is no freshwater criterion set for Manganese. In the absence of an aquatic health criterion, the EPA human health consumption criterion of 50 ug/L was used to define exceedances.

Dissolved Oxygen concentration is the final parameter selected for analysis in this report. Dissolved oxygen concentrations above designated thresholds are essential for the survival of aquatic vertebrates and invertebrates, while low values suggest nuisance algae populations stemming from nutrient pollution. Several different criteria have been specified, due to the varying tolerances of adult and juvenile, warm water and cold water species. For the purposes of this investigation, the one-day minimum, coldwater fishery criterion of 4 mg/l (USEPA, 1986) is employed. This criterion is thought to be the most appropriate because the limit will include all warm water violations, without including samples that would be flagged using the coldwater, juvenile fish criteria (juvenile fish are prevalent during the spring, when mechanical saturation provides sufficient oxygen levels in all but the most impaired watersheds. These watersheds will be identified using the one-day minimum coldwater fishery criteria or via one of the other chemicals).

From the results in Table 4, it can be seen that fecal coliform is still a contaminant of concern in the Bluestone River watershed. In fact, the upward trends noted for the stations located on the Bluestone River (BLUE_B01), the Little Bluestone River (BLUE_B02), and Mountain Creek (BLUE_B05) appear to confirm the inclusion of these three streams on West Virginia's 303d list as shown in Table 3. Although the contaminant was identified as coming from "unknown" sources by DEP, it is probable that it originates from untreated wastewater in rural areas.

Another potential problem is mine drainage. Although not identified as such by the West Virginia DEP in recent stream assessments completed in the area, the elevated specific conductance measurements noted at stations BLUE_B01, BLUE_B03, and BLUE_B04 suggest that mine drainage may still be a problem in this watershed. However, given that most of these measurements are relatively old, it is possible that mine-related problems have been diminishing over time due to the decrease in mining activity over the last 20 years. Any potential problems with mine drainage would most likely be limited to the Bluestone River itself since the mining areas within the larger Bluestone River watershed as identified in Figure 1 are located in the upper reaches of the watershed.

TMDL Development

The West Virginia Department of Environment Protection (DEP) is planning to conduct total maximum daily load (TMDL) assessments for the impaired waters in and around the park discussed in previous sections. A TMDL is essentially a plan of action used to clean up streams that are not meeting water quality standards. The plan includes pollution source identification and strategy development for contaminant source reduction or elimination. As of the date of this document (September 2004), no TMDLs have been developed for any of the "303d-listed" waters within the Bluestone River watershed, including those within the Bluestone NSR. Currently, the West Virginia DEP has plans to develop TMDLs for all of these impaired waters by the end of 2007.

Presence of Existing Gages and Monitoring Sites

At present, there is only one active USGS stream flow gage in, or located in close proximity to, the Bluestone NSR (see Figure 1). This gage (3179000) is located at the upper end of the park near Pipestem State Park. With respect to water quality monitoring stations, there appear to be no active, long-term monitoring stations within, or in the immediate vicinity of, the park.

Recommendations for Future Monitoring

Based on the analyses presented above, it appears that elevated fecal coliform levels are still prevalent in waters flowing into and through the Bluestone NSR. Problems with pH and elevated metal concentrations have been experienced in the past, and mine drainage from the western part of the watershed (particularly near Rich Creek) may still be impacting waters flowing through the park as suggested by relatively high specific conductance values observed at monitoring stations located on the Bluestone River in the 1990's.

In the past, several water quality monitoring stations were used to monitor fecal coliform and mine drainage problems in various sub-watersheds (see stations 551002, BLUE_B01, BLUE_B02, BLUE_B03, BLUE_B04, BLUE_B05, KNB-000-004.3, KNB-000-006.0, and KNB-000-011.8 in Figure 7), but these stations have since been discontinued. Some of these or similar stations need to be re-established in order to properly assess such problems in preparation for TMDL assessments completed for the Bluestone River and tributaries in the future.

As discussed in a previous section, the West Virginia DEP is planning to complete all required TMDLs for 303-listed waters in the Bluestone River watershed by the end of 2007. It is likely that the DEP will conduct "pre-TMDL" stream sampling in a number of streams in the area as it is currently doing in other watersheds around the state. However, it is not known exactly when this will occur; although it is likely that such monitoring will start within the next year or so. In the meantime, it might be worth considering the re-establishment of at least 3 monitoring stations in the park in anticipation of future TMDL assessments done for the Bluestone River, Little Bluestone River, and Mountain Creek. Two of these stations should be established for the Little Bluestone River and Mountain Creek near the sites of the older "551002" and "BLUE_B05" stations, respectively, shown in Figure 7. In both cases, focus should be placed on monitoring for fecal coliform. The third station should be located at the upstream edge of the park, about a mile or so upstream of the old "KNB-000-011.8" station. In this case, fecal coliform should be measured, as well as a suite of mine-related parameters such as pH, specific conductance, aluminum, and iron in order to determine if mine drainage is still affecting the Bluestone River due to mining activities in the upper reaches of the watershed. An optional fourth station might also be useful to assess the quality of water as it leaves the park; although this is probably not necessary since it appears that water quality problems observed within the park originate from sources and activities outside of it. Such a station could be located near the older BLUE_B01 site, and be set up to measure primarily for fecal coliform and various mine-related parameters as described above.

Literature Cited

National Park Service, 1995. Baseline Water Quality Data Inventory and Analysis: Bluestone National Scenic River, Tech. Report NPS/NRWRD/NRTR-95-73, 377 pp.

Sheeder, S. A. and B.M. Evans, 2004. Estimating Nutrient and Sediment Threshold Criteria for Biological Impairment in Pennsylvania Watersheds. Journal of the American Water Resources Association (JAWRA) 40(4): 881-888.

USEPA (U.S. Environmental Protection Agency), 2002a. List of Drinking Water Contaminants & MCLs. EPA 816-F-02-013, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2002b. Implementation Guidance for Ambient Water Quality Criteria for Bacteria. EPA-823-B-02-003, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2002c. National Recommended Water Quality Criteria: 2002. EPA-822-R-02-047, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 1986. Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003, U.S. Environmental Protection Agency, Washington, D.C.

WATER QUALITY SUMMARY

for

DELAWARE WATER GAP NATIONAL RECREATION AREA

September 2004

Overview of Park/Watershed Characteristics

The Delaware Water Gap National Recreation Area (DEWA) is approximately 68,594 acres (107.2 mi^2) in size, and is almost entirely forested with small amounts of row crop / agricultural land distributed throughout the park and low-density development land located in the upstream most region of the park. The watershed within which the park is located is depicted in Figure 1. The watershed is 2,666,962 acres (4167 mi^2) in size. The land use/cover within this watershed is approximately 80% woodland, with the remaining 20% comprised of agricultural land and a very small urban/residential development contribution.

Figure 1 depicts all USGS stream discharge monitoring stations that are used in the current analysis. These gages are used within this report to evaluate flow and pollutant loads generated in different portions of the watershed. As measured at the USGS gage downstream of the park, the mean daily surface water flow within the Delaware River at the Delaware Water Gap (USGS gage 1446500) is about 7776 cfs, based upon a period of record between 1922 and 2002. Eliminating all flow data prior to 1990 from the analysis yields a mean daily surface water flow of 7495 indicating that flow conditions in the Delaware river between 1990 and 1996 reflect slightly lower flow conditions than the average conditions recorded over the entire period of record. Temporal variations in flow on a mean annual basis are depicted in Figure 2.

For the purposes of this analysis, various sub-areas within the larger watershed have been defined based on the location of other USGS gages as shown in Figure 1. Table 1 presents information on the relative contributions of each of these smaller sub-watersheds in terms of area and mean annual flows. (These gages are also used in the estimation of nutrient and sediment loading rates as described later in this report). Sub-area 1 corresponds to USGS gage 1434000 and is essentially the drainage area for the Delaware River beginning at the upstream boundary of the Delaware Water Gap NRA. Sub-area 2 corresponds to the Delaware River drainage upstream of USGS gage 1438500 located at Montague, NJ (that is, it includes Sub-area 1). Sub-area 3, represented by USGS gage 1440000 is the Flat Brook watershed upstream of Flatbrookville, NJ. The Bushkill watershed upstream of shoemakers, PA corresponds to sub-area 4 (USGS gage 1439500). Sub-area 5 corresponds to the Delaware River drainage upstream of USGS gage 1440200 located at the Delaware Water Gap (and, therefore includes Sub-areas 1-4). USGS gage 1442500 monitors the Broadhead Creek watershed upstream of Minisink Hills, PA and is represented as sub-area 6. The USGS gage 1446500 is located on the Delaware River at Belvidere, NJ. This gage is used to calculate the contribution of each sub-area to total flow. It is not used for the nutrient and sediment loading analysis discussed in upcoming sections since there is no co-located chemistry data available at this site.

Figure 1. Location of park, watershed outlets and USGS gages within Delaware River drainage.

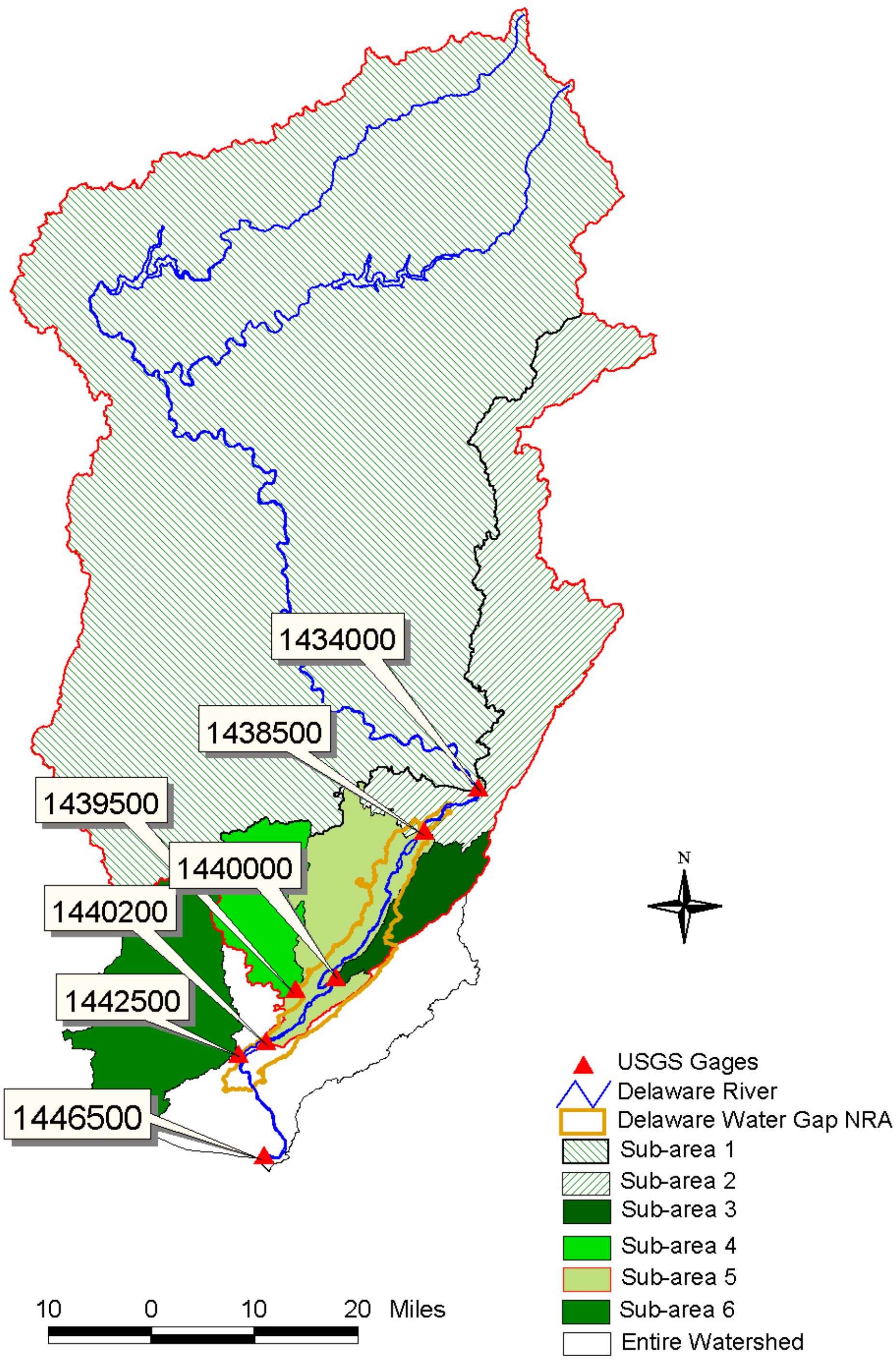


Figure 2. Representative mean annual hydrograph of flows for the Delaware River at gage 1446500, approximately 4 miles downstream of Delaware Water Gap NRA (derived from 1922 – 2002 data)

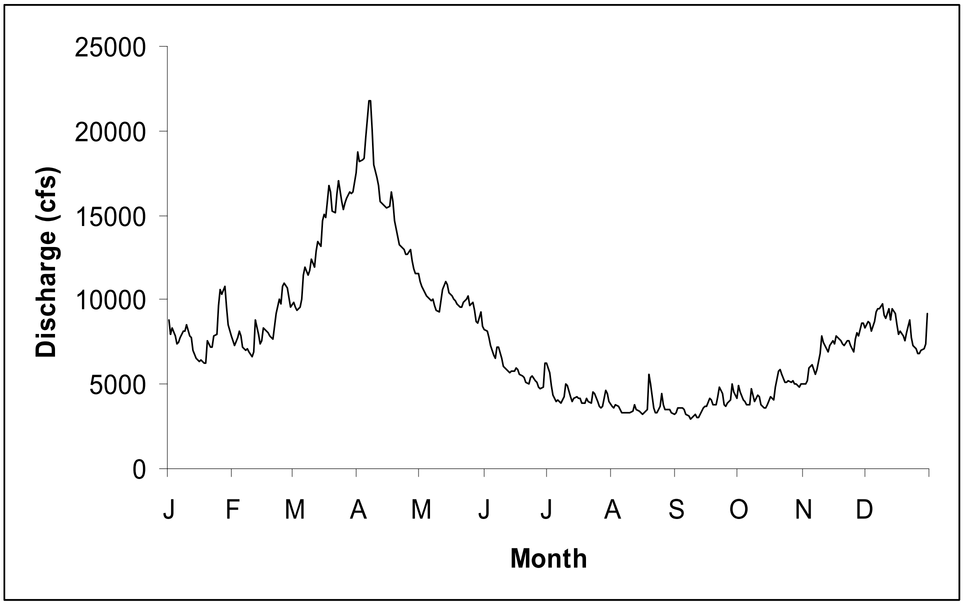


Table 1. Flow characteristics of sub-watersheds.

Watershed	USGS Gage	Mean Daily Flow (cfs)	% of Total Drainage Area	% of Contributed Mean Annual Flow
Entire Watershed[1]	1446500	7776	100%	100%
Sub-area 1	1434000	5161	70%	66%
Sub-area 2	1438500	5646	80%	73%
Sub-area 3	1440000	110	2%	1%
Sub-area 4	1439500	235	3%	3%
Sub-area 5	1440200	6208	88%	80%
Sub-area 6	1442500	558	6%	7%

[1]Gage 1446500 is only utilized to illustrate the relative contribution of the other gaging stations to total watershed flow. A co-located water chemistry station does not exist at this site.

Historical Water Quality Overview

Detailed analyses of water quality within and around the Delaware Water Gap NRA, as well as other national parks, has previously been prepared by the Water Resources Division (WRD) of the National Park Service (NPS, 1995). These reports are commonly referred to as "Horizon" reports after the contractor that performed most of the analyses (Horizon Systems). A Horizon report was completed for the Delaware Water Gap NRA and the Upper Delaware Scenic and

Recreational River (UPDE) using data collected between 1950 and 1993 (sulfate and nitrate data extend as far back as 1923, all other parameters were measured beginning in 1950 or later) at sites located within a region extending three miles upstream and one mile downstream of the park boundaries. Based upon these temporal and spatial criteria, data from 105 water chemistry sampling stations, 35 stream discharge gaging stations, and 35 industrial/municipal dischargers were retrieved from a variety of federal and state sources (EPA, USGS, DRBC, PADEP, etc.). It should be noted here, however, that due to the size of the DEWA and UPDE properties and the temporal extent of the data used in the analysis, some of the results presented in the earlier report (and summarized below) may not be relevant with respect to water quality issues currently facing these two parks.

In the Horizon report, it was noted that 20 different water quality parameters exceeded the screening criteria used in the study at least once within the study area. Dissolved oxygen, pH, cadmium, copper, lead, mercury, zinc, enterococci, total residual chlorine, nitrite, nitrate, nitrite plus nitrate, sulfate, cadmium, nickel, vinyl chloride, methylene chloride, coliform bacteria (total and fecal) concentrations, and turbidity each exceeded one or more of the screening criteria. Screening limits used include the WRD primary body contact recreation and aquatic life criteria, EPA drinking water criteria, and EPA criteria for the protection of freshwater aquatic life. Based on the results of this study, it was believed by the authors that surface waters within the study area are of generally good quality, with indications of some impacts from human activities. The authors concluded that any aquatic degradation could likely be attributed to increasing development of surrounding properties resulting in sedimentation and increased stormwater runoff, short circuiting septic systems, discharges from wastewater treatment facilities, and atmospheric deposition.

Many of the contaminant exceedances described above may not be particularly relevant today either because of very low exceedance percentages (dissolved oxygen exceeded criteria 11 times out of 6658 samples, nitrate exceeded criteria 5 times out of 2479 samples), or because such exceedances occurred over 20 years ago. Based on the above limitations, it appears that the primary pollutants of present concern include pH, bacteria (total coliform, fecal coliform, and enterococci), and lead. These concerns are further supported by 303d listing of several surface water bodies in and around the Delaware Water Gap NRA for similar impairments (as discussed in a later section).

Specially Designated Surface Water Bodies

According to the Pennsylvania and New Jersey state geographic information system surface water files, there are over 200 miles of streams located within the DEWA park boundary that have a designated use and/or anti-degradation policy associated with the water body. Figure 3 depicts these water bodies and their associated designations. Since states are responsible for individually assessing the use and protection of surface water bodies, the surface water designations are defined differently for each state.

The Pennsylvania designations include ‘high quality’ and ‘exceptional value’ waters. In Pennsylvania, high quality waters must meet one or more of the following conditions:

1. The water has long-term water quality (>1 year of data collection) that exceeds levels necessary to support the propagation of fish, shellfish, and wildlife and recreation in and on the water.
2. The surface water supports a high quality aquatic community based upon data gathered using peer-reviewed biological assessment procedures

Exceptional value waters must:

1. meet all requirements of high quality waters and additionally meet the requirements of one or more of the following:
    a. The water is located in a designated State park natural area, state forest natural area, National natural landmark, Federal or State wild river, Federal wilderness area or National recreation area
    b. The water is located in a National wildlife refuge or a State game propagation and protection area
    c. The water is an outstanding National, State regional or local resource water
    d. The water is a surface water of exceptional recreational significance
    e. The water is designated as a "wilderness trout stream" by the Fish and Boat Commission following public notice and comment
2. be of exceptional ecological significance.

Pennsylvania high quality and exceptional value waters are afforded additional protection in order to maintain their current status. The additional regulations include protection against point source discharging facility development, stringent controls on existing municipal and industrial dischargers, and non-point source pollution controls (best management practice implementation). Further detail on these policies can be found in Title 25, Chapter 93 of the Pennsylvania Code.

The State of New Jersey supports three different designations; category 1 (C1), category 2 (C2), and outstanding national resource (ON) waters.

1. Category 1 waters are designated for protection from measurable changes in water quality characteristics because of their clarity, color, scenic setting, other characteristics of aesthetic value, exceptional ecological significance, exceptional recreational significance, exceptional water supply significance, or exceptional fisheries resource(s).
2. In category 2 waters, water quality characteristics that are generally better than, or equal to, the water quality standards are maintained within a range of quality that protects the existing/designated uses of the water body. Existing water quality will be protected from changes that might be detrimental to the ecosystem, and water quality characteristics that are generally worse than established water quality criteria will be improve to that level.
3. Outstanding National (ON) resource waters are high quality waters that constitute an outstanding national resource (for example, waters of National Parks, State Parks and Wildlife refuges and waters of exceptional recreational or ecological significances). FW1 and PL waters within the state are protected under this anti-degradation policy. These waters include:
    a. FW1: waters set aside for posterity to represent the natural aquatic environment and its associated biota and maintenance, migration and propagation of the natural and established biota

b. PL: waters reserved for cranberry bog water supply and other agricultural uses, water reserved for maintenance, migration and propagation of the natural and established biota indigenous to this unique ecological system, water reserved for public potable water supply after conventional filtration treatment, and water reserved for primary and secondary contact recreation

Anti-degradation policies state that New Jersey waters with C1 and C2 designations shall be maintained and protected, or returned to such a state as soon as technically and economically feasible. No changes are allowed in ON-designated waters that may affect these outstanding resource waters. Additional information on these policies can be found in New Jersey Surface Water Quality Standards publication N.J.A.C. 7:9B.

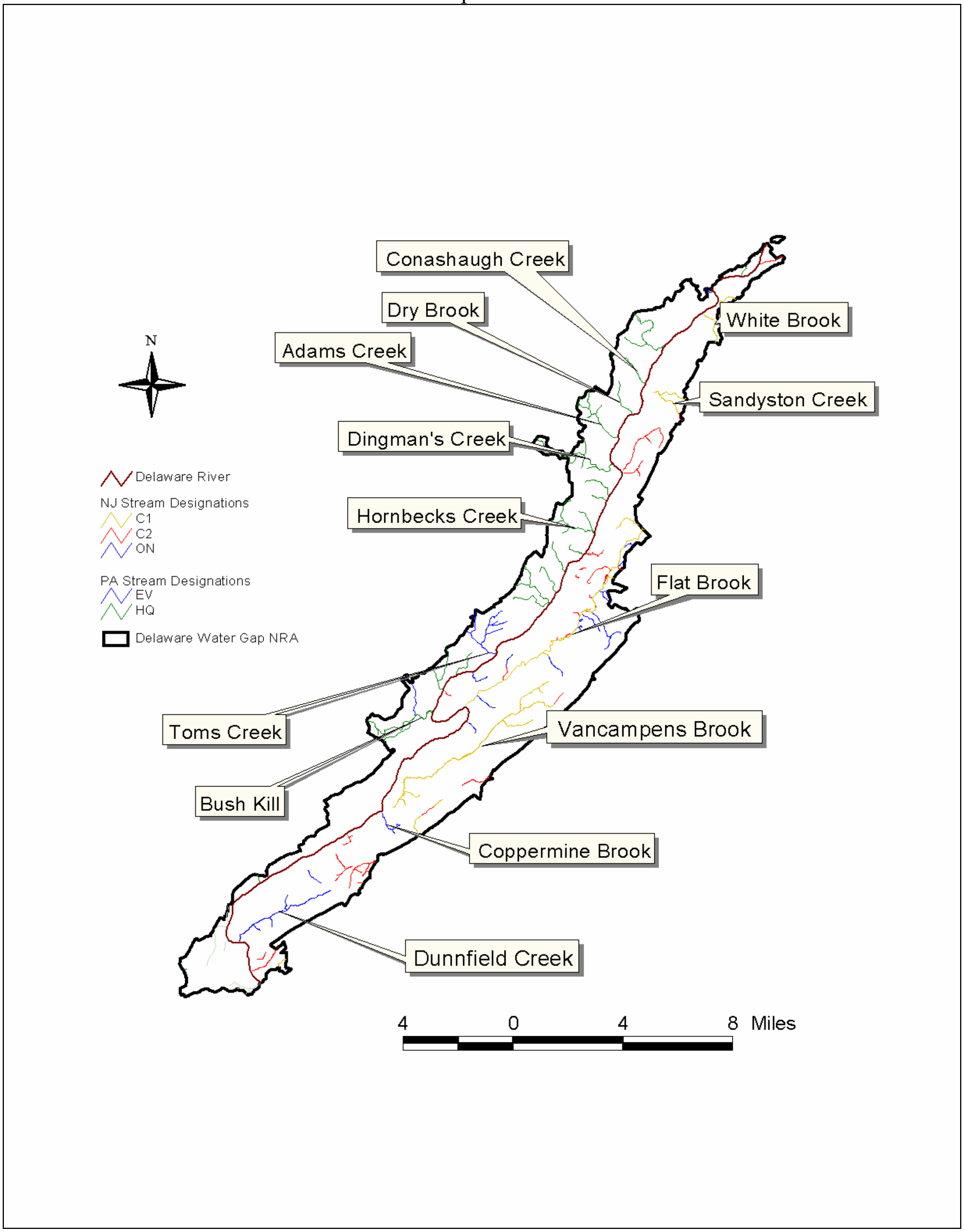
In December 1992, the mainstem of the Delaware River was designated as 'special protection waters' by the Delaware River Basin Commission (DRBC) with the support of the NPS. The stretch of the Delaware afforded this special protection begins upstream of the UPDE boundary and extends to the downstream boundary of DEWA, thereby encompassing both NPS properties located on the Delaware River. Associated with this special designation, DRBC has adopted a policy that states, "there be no measurable change in existing water quality except towards natural conditions" within this region. In order to evaluate changes in the existing water quality, data for 14 parameters at UPDE and 16 parameters between Millrift, PA and the downstream boundary of DEWA were collected (DRBC, 1996). These data were used to establish regulatory standards against which changes in water quality can be evaluated.

Current Listing of Water Quality Impairments

As shown in Figure 4, several surface water bodies within the Delaware Water Gap NRA have been identified as being impaired on the Pennsylvania and New Jersey 303d lists. As can be seen from Figure 3, all or portions of the Flatbrook, Dunnfield, and Bush Kill basins have also been designated as "special" or worthy of protection based on one or more criteria. Table 2 provides information on the impaired surface water bodies either in or immediately adjacent to the Delaware Water Gap NRA. In all cases, the 'sources' have been listed as 'unknown'.

Bush Kill Creek, Dunnfield Creek and the Delaware River are all listed for impairment due to Mercury. While the official source of pollution is listed as 'unknown', it is very likely that these impairments are associated with atmospheric deposition (Mercury emission to the atmosphere is a byproduct of coal combustion) and specific properties of mercury, which allow mercury compounds to bio-accumulate in the tissue of aquatic organisms. The mainstem of the Delaware River is also listed for impairment due to PCB contamination. High concentrations of PCBs have been measured in the Delaware estuary. Similar to Mercury, PCBs accumulate in the tissue of aquatic organisms. Since the Delaware River remains free-flowing, many of these infected organisms are free to migrate throughout the Delaware, spreading the PCB contamination from the estuary (the site of original contamination) to other reaches of the river. The Delaware River, upstream of the estuary, was listed on the 303d list because 1995 samples of American Eel tissue contained elevated levels of these chemicals. For further information on the status of PCB contamination, modes of contamination, and TMDL development contact Robert Frey of the Pennsylvania State Department of Environmental Protection (717-787-9637).

Figure 3. Streams with specific anti-degradation policies, located within the Delaware Water Gap NRA



Dunnfield Creek is listed for an extensive suite of physical, biological and chemical parameters. Again, sources of the impairments are listed as ‘unknown’, but it is very likely that the problems are associated with atmospheric deposition of nitric and sulfuric acid (which are harmful byproducts of coal and petroleum combustion), low watershed buffering capacity, faulty septic systems, and/or point sources (according to the DEWA Horizon report, there are very few dischargers in the watershed) within the region.

Lastly, Flat Brook and Dunnfield creek list macroinvertebrates as a cause of impairment. While officials at the New Jersey Department of Environmental Protection were not available for comment, the introduction of a non-native invertebrate species could explain these listings. Introduced invertebrate species can have an adverse affect on the native biological community through competition for habitat and/or food, or predation.

Out of approximately 180 miles of streams located within the park, about 33% (59.5miles) have been designated as being water quality-impaired.

Figure 4. Location of impaired surface water bodies on 303d list.

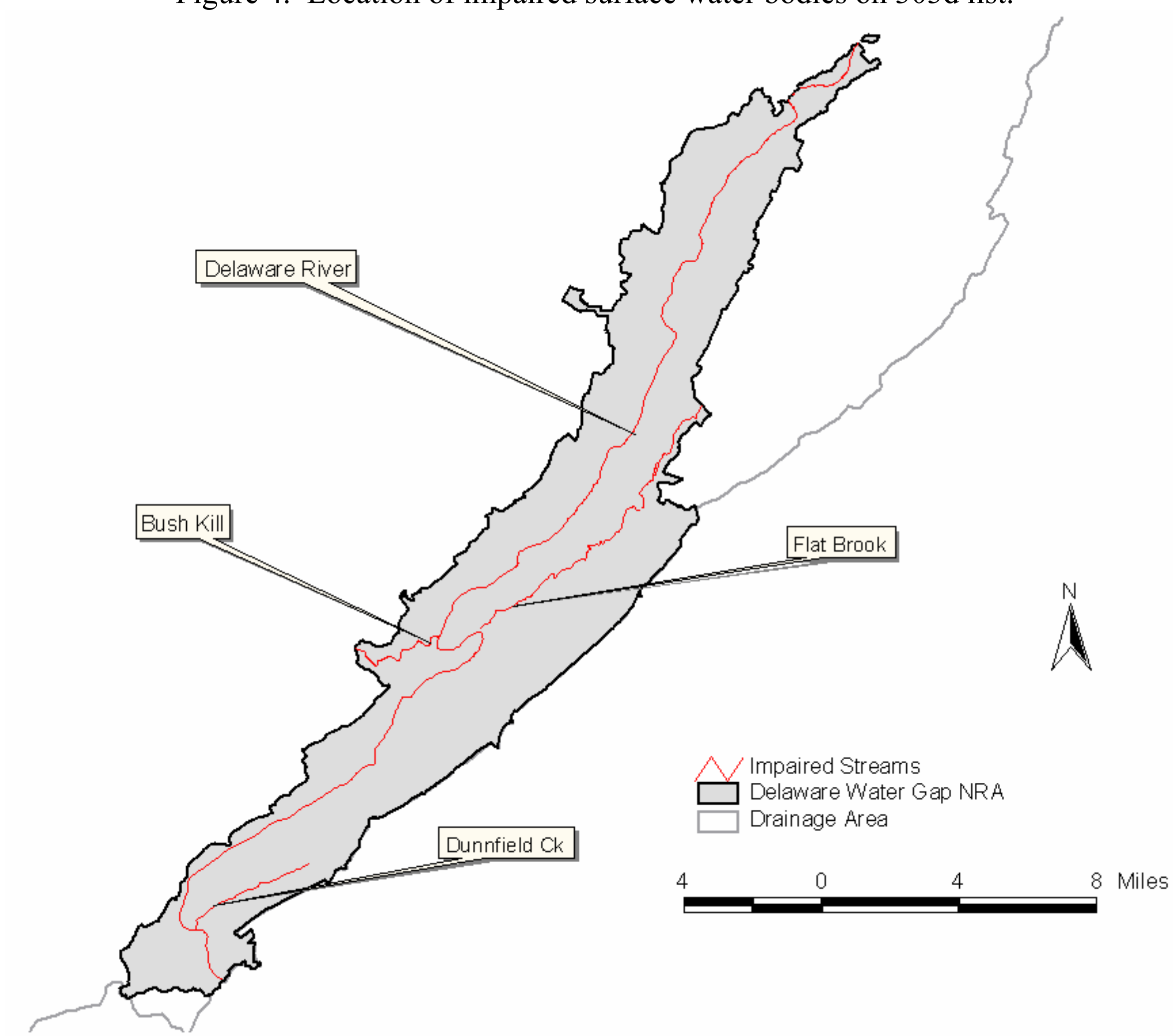


Table 2. Sources and causes of listed impairments.

Surface Water Body	Cause	Source	Impaired Miles within the Park
Bush Kill	Mercury	Unknown	3.51
Delaware River	Mercury, PCB	Unknown	40.97
Dunnfield Creek	Phosphorus, Fecal Coliform, Temperature, Dissolved Oxygen, Nitrate, Dissolved Solids, Total Suspended Solids, Unionized Ammonia, Chromium, Copper, Nickel, Selenium, pH, Arsenic, Cadmium, Lead, Mercury, Silver, Zinc, Benthic Macroinvertebrates	Unknown	4.068
Flat Brook	Benthic Macroinvertebrates	Unknown	10.93

Current Water Quality Trends and Loading Rates

Using more recently-compiled water quality data, mean annual concentration values for selected parameters were compared with criteria similar to those used in the earlier Horizon reports to assess whether potential water quality problems identified in the past still exist. These selected parameters were based on various factors, including past problems described in the Horizon report, problems identified in the 303d listings, and the list of core parameters to be used as "vital sign" indicators as identified by WRD. Temperature is also listed as one of the core parameters, but was not included here for several reasons. First, there are no established temperature criteria to use to evaluate the condition of the aquatic system. Secondly, trends in temperature could be evaluated but the results may prove misleading due to natural long-term air temperature trends and the relationship between air and water temperature (i.e. gradual warming of mean annual water temperature may reflect recent warming of the climate, and not watershed disturbance).

Temporal trends for selected water quality parameters were also determined to provide a sense of potential changes in such parameters over time (i.e., are problems getting worse or better?). Temporal trends were evaluated for each constituent that exceeded concentration criteria during the period of analysis (1990-present). To determine the existence of a temporal trend, concentration values were plotted against date and fit with a linear trendline in MS Excel. Additionally, loading rates for total nitrogen, phosphorus and suspended sediment were estimated for six sub-areas (Figure 1) affecting water quality in the park. These loads were calculated to provide another measure of potential water quality problems.

Based upon information provided in previous sections, water quality statistics and trends were determined for total nitrogen, total phosphorus, specific conductivity, pH, fecal coliform, mercury, iron, aluminum, manganese, and dissolved oxygen where the appropriate data were available (see Table 3). In all cases, an attempt was made to use any sample data collected from 1990 up to the present. However, as can be seen from Table 3, data from some of these sites were only as recent as 1995. These parameters were selected because they are commonly used to assess certain aspects of the hydrologic system, and are briefly discussed below. For this analysis, all stations for which data were compiled, and those stations that exceeded the water quality criteria outlined below, are shown in Figure 5.

Specific Conductivity is the ability of a substance to conduct an electrical current across a given length at a specified temperature. Specific Conductivity can be used as an indicator of water quality because pure water has a very low electrical conductance. As concentrations of different ions dissolved in water increase, so does the conductivity. Therefore, conductivity is directly related to the amount of charged particles (i.e. heavy metals, clay particles, etc.) contained within a water sample. While there are no set conductivity criteria for fresh water, specific conductance is linearly related to the concentration of total dissolved solids in a sample. For the purposes of this investigation,

$$0.65*K = S$$

where K is conductance (micromhos) and S is dissolved solids (mg/L). The EPA has a recommended criterion of 500 mg/L for dissolved solids in drinking water (US EPA, 2002a). This corresponds to a specific conductivity of 325 micromhos, given the equation above.

pH is one of the most general indicators of water quality. The natural logarithm of hydrogen ion concentration in solution, pH ranges from 0-14 with 7 being neutral. pH values ranging from approximately 6-8 naturally occur in freshwater aquatic systems. The EPA-established criterion for aquatic life protection includes pH values between 6.5 and 9.0. For the purposes of this investigation, recorded values outside of this range were flagged as an indication of impairment.

Fecal Coliform bacteria levels were used as an indicator of failing sewage treatment facilities or otherwise untreated wastewater upstream of a sampling point. In discussion of indicator bacteria, it should be noted that the EPA recommends the analysis of either E. Coli or enterococci bacteria for this purpose. However, there are very few samples of E. Coli and enterococci bacteria available for assessment of aquatic ecosystem health. Therefore, Fecal Coliform data were examined using an EPA (2002b) established threshold of 200 colony forming units (CFU).

High loads and or concentrations of *Total Nitrogen, Total Phosphorus, and Total Suspended Sediment* are often correlated with excessive fertilization of agricultural land, ineffective agricultural management strategies, high levels of impervious surface area, and other anthropogenic disturbances within the watershed. No nationally recognized criteria exist for these three parameters, so criteria published by Sheeder and Evans (2004) were employed. The criteria were developed for the state of Pennsylvania, and are though to be relatively accurate for regions of New York and West Virginia as well. The criteria for total nitrogen, total phosphorus, and total suspended sediment are 2.01 mg/L, 0.07 mg/L, and 197.27 mg/L respectively.

Elevated concentrations of *Mercury, Iron, Aluminum, and Manganese* and many other metals are commonly associated with large-scale disturbances within a watershed including mining and large-scale construction projects. Elevated metals concentrations can also result from acidic deposition, low watershed acid buffering capacity, and other factors. These four metals were selected from the larger suite of metals associated with mining/disturbance impairments because each has been explicitly implicated as the cause of impairment in section 303d-listed watersheds in Pennsylvania, West Virginia, New York and/or New Jersey. The EPA has published criterion for each of the metals analyzed in this report (USEPA, 2002c). Mercury is designated as a priority pollutant, and has a freshwater CMC criterion of 1.4 ug/l. Iron, Aluminum and Manganese are listed as non-priority pollutants. Iron and Aluminum are assigned freshwater criteria of 1000 ug/L (CCC) and 750 ug/L (CMC), respectively. There is no freshwater criterion set for Manganese. In the absence of an aquatic health criterion, the EPA human health consumption criterion of 50 ug/L was used to define exceedances.

Dissolved Oxygen concentration is the final parameter selected for analysis in this report. Dissolved oxygen concentrations above designated thresholds are essential for the survival of aquatic vertebrates and invertebrates, while low values suggest nuisance algae populations stemming from nutrient pollution. Several different criteria have been specified, due to the varying tolerances of adult and juvenile, warm water and cold water species. For the purposes of this investigation, the one-day minimum, coldwater fishery criterion of 4 mg/L (USEPA, 1986) is employed. This criterion is thought to be the most appropriate because the limit will include all warm water violations, without including samples that would be flagged using the coldwater, juvenile fish criteria (juvenile fish are prevalent during the spring, when mechanical saturation provides sufficient oxygen levels in all but the most impaired watersheds. These watersheds will be identified using the one-day minimum coldwater fishery criteria or via one of the other chemicals).

From the results in Table 3 it can be seen that pH, fecal coliform bacteria, and phosphorus appear to be the predominant pollutants affecting the Delaware Water Gap NRA. Likely sources of these problems include acidic deposition in conjunction with low buffering capacity, short-circuiting and damaged septic systems, and agricultural (and golf courses) activities for pH, fecal coliform bacteria, and phosphorus, respectively. More specifically, six sites upstream of DEWA and two sites at the southern end of the park all indicate that a combination of pH, fecal coliform bacteria, phosphorus and manganese are causing some level of impairment in the Delaware River.

All stations (with appropriate data) included in this analysis were analyzed for violations in the mercury criteria, with no results returned. The discrepancy between this result and the 303d listing of the Delaware River for impairment due to Mercury can be explained by the behavior of mercury in aquatic systems. Mercury is lipophylic, meaning that the metal accumulates in the fatty tissues of biological organisms. As prey organisms are consumed by predators, the mercury present in the prey species is transferred up the food chain. This results in elevated concentrations of mercury in the tissues of predatory species. Therefore, the Delaware River is listed on the PA 303d list due to elevated levels of mercury in fish tissue, while the instream concentrations remain below the established EPA criteria.

Data from this analysis also indicate that many of the tributaries entering the Delaware River within the DEWA property also appear to be at risk of impairment. The chemicals violating the criteria used here principally include fecal coliform bacteria, phosphorus, and pH with several stations also indicating impairment due to manganese. As mentioned above, low pH results are likely due to a combination of acidic atmospheric deposition and low watershed buffering capacity. The primary sources of phosphorus pollution are likely sewage treatment facilities, agricultural practices and golf courses (this is highly probable at station DRBC/NPS272, located at the Shawnee Creek Golf Club bridge). While high fecal coliform bacteria counts can occur naturally, the high number of stations violating the established criteria suggest that there are short-circuiting septic systems in the watershed. Bushkill Creek and Flat Brook are also listed as impaired on the NJ and PA 303d lists. This assessment is corroborated by the analysis of stations located in these basins. Many of these stations indicate fecal coliform bacteria, phosphorus, and pH impairment. The reasons for these impairments are likely similar to those described above.

In addition to the water quality trend analyses described above, mean annual loading rates for selected pollutants in the watershed were also done. More specifically, loading rates were estimated for sub-areas 1-6 (Figure 1). It was not possible to calculate loading rates for the entire watershed since there was no water quality monitoring station located near the USGS flow gage (1446500) that defines this watershed.

Total nitrogen, total phosphorus and total suspended sediment loading rates were estimated for each sub-area, given water quality data availability (see Table 4). These estimates were subsequently compared with “threshold” loading rates developed by Sheeder and Evans (2004) for evaluating watersheds in Pennsylvania. These threshold values (also shown in Table 4) reflect values above which watersheds are believed to show signs of water quality impairment. Based on these particular criteria, it appears that nutrient and sediment loads do not represent a significant water quality problem in the sub-areas that were analyzed. It is important to note that, while the sub-area 5 and sub-area 6 unit area phosphorus loads do not exceed the established loading criteria they are very close. The water quality analysis did not return any phosphorus violations at the stations associated with sub-area 5. However phosphorus criteria violations do exist at the water quality stations associated with sub-area 6 (WQN0137 and DRBC/NPS27). The trend analysis of phosphorus data at these two stations yielded conflicting results (increasing P concentrations at DRBC/NPS27 and decreasing P concentrations at WQN0137), and therefore no projections of future conditions can be made.

TMDL Development

The New Jersey and Pennsylvania Departments of Environment Protection (DEP) are planning to conduct total maximum daily load (TMDL) assessments for the impaired waters discussed in previous sections. A TMDL is essentially a plan of action used to clean up streams that are not meeting water quality standards. The plan includes pollution source identification and strategy development for contaminant source reduction or elimination. As of the date of this document (September 2004), no TMDLs have been developed for any of the “303d-listed” waters within the Delaware Water Gap NRA property. The PA DEP is legally mandated to complete TMDL assessments in the order that the streams are listed, and to demonstrate sufficient progress (as determined by legal court review) on an annual basis. The PA DEP is currently working on impaired water bodies listed during the 1998-2000 Assessment round. All water bodies listed after this date will be assessed in the order that they were evaluated.

Table 3. Results of analyses based on 1990-2004 water quality data at stations in and around Delaware Water Gap NRA.

Station ID	Station Name	Chemical Characteristic	Violations	Sample Count	% Violation	Begin Date	End Date	Min. Value	Max. Value	Avg. Value	Trend
14010001	DELAWARE R., PORT JERVIS @ RT.6/209 BR.	pH (Standard Units)	7	36	19.4%	Nov-90	Sep-98	6.18	7.31	6.77	-
DRBC/NPS002	DELAWARE R., AT DEWA BOUNDARY, CEMENT WALL ALONG CREEK	Fecal Coliform (CFU/100mL)	3	19	15.8%	Jul-92	Sep-93	5	1840	167	NA
		Phosphorus, Total (mg P/L)	2	17	11.8%	Sep-91	Sep-93	0.01	0.52	0.06	NA
DRBC/NPS1111	DELAWARE R., PORT JERVIS/MATAMORAS BR. (NY)	Fecal Coliform (CFU/100mL)	19	24	79.2%	Jun-90	Jul-97	75	810	338	+
DRBC/NPS2251	LITTLE FLATBROOK AT PETERS VALLEY	Fecal Coliform (CFU/100mL)	4	38	10.5%	Jul-92	Oct-98	4	400	83	+
		Sp. Cond. (UMHOS/CM @ 25C)	9	37	24.3%	Jul-92	Oct-98	70.2	400	245.43	-
DRBC/NPS252	DELAWARE R., UPSTREAM OF MILFORD LANDING	Fecal Coliform (CFU/100mL)	2	18	11.1%	Jul-90	Jun-93	7	400	61	NA
DRBC/NPS253	NEVERSINK RIVER, ROUTE 6 BR. (COMPOSITE)	Fecal Coliform (CFU/100mL)	2	20	10.0%	Jul-92	Aug-97	2	266	84	-
DRBC/NPS26	CHERRY CREEK, NEAR RT 80 BRIDGE	Fecal Coliform (CFU/100mL)	39	75	52.0%	Jun-90	Oct-98	1	4000	312	-
		Phosphorus, Total (mg P/L)	25	36	69.4%	Jun-90	Sep-93	0.029	0.423	0.12	-
DRBC/NPS261	CHERRY CREEK, DEL WATER GAP BORO	Fecal Coliform (CFU/100mL)	6	13	46.2%	Aug-92	Sep-93	23	800	255	NA
DRBC/NPS27	BRODHEAD CREEK, RT 402 BRIDGE	Fecal Coliform (CFU/100mL)	21	74	28.4%	Jun-90	Oct-98	1	2000	197	NA
		Phosphorus, Total (mg P/L)	27	38	71.1%	Jun-90	Sep-93	0.01	0.9	0.16	+
DRBC/NPS271	SHAWNEE CREEK, RESORT PARKING LOT (PA)	Fecal Coliform (CFU/100mL)	30	69	43.5%	Jun-90	Oct-98	1	1600	262	-
DRBC/NPS272	SHAWNEE CREEK, GOLF CLUB BRIDGE	Fecal Coliform (CFU/100mL)	11	16	68.8%	Aug-92	Aug-94	1	1280	403	-
		Phosphorus, Total (mg P/L)	3	14	21.4%	Aug-92	Sep-93	0.01	0.333	0.08	+
DRBC/NPS28	MARSHALLS CREEK, MINISINK HILLS BRIDGE	Fecal Coliform (CFU/100mL)	5	21	23.8%	Jun-90	Aug-93	10	1028	175	-
DRBC/NPS33	BUSHKILL CREEK, RT 209 BRIDGE	Phosphorus, Total (mg P/L)	7	22	31.8%	Jun-90	Sep-93	0.01	0.165	0.06	-
DRBC/NPS342	SAW CREEK, BUSHKILL CREEK CONFLUENCE (PA)	Fecal Coliform (CFU/100mL)	3	30	10.0%	Jun-90	Sep-93	1	256	71	+
DRBC/NPS41	HORNBECK CREEK, RT 209 BRIDGE	Fecal Coliform (CFU/100mL)	2	15	13.3%	Jun-90	Sep-92	1	228	54	NA
DRBC/NPS411	HORNBECKS CREEK, DEWA BOUNDARY (PA)	Fecal Coliform (CFU/100mL)	5	25	20.0%	Jun-90	Sep-93	3	492	129	+
		Phosphorus, Total (mg P/L)	2	19	10.5%	Jun-90	Sep-93	0.019	0.102	0.04	-
DRBC/NPS421	DINGMANS CREEK, DEWA BOUNDARY (PA)	Phosphorus, Total (mg P/L)	2	16	12.5%	Jun-90	Sep-93	0.01	0.24	0.04	NA
DRBC/NPS47	SHIMERS BROOK, RT 521 BRIDGE	Sp. Cond. (UMHOS/CM @ 25C)	12	75	16.0%	Jun-90	Oct-98	53	368	240	-
DRBC/NPS50	NEVERSINK RIVER, RT 6 BRIDGE	Fecal Coliform (CFU/100mL)	9	54	16.7%	Jun-90	Aug-98	1	1100	113	NA
		Phosphorus, Total (mg P/L)	21	28	75.0%	Jun-90	Sep-93	0.01	0.164	0.09	-
WQN0103	DELAWARE R., US RTES 6 & 209 BR	Manganese, Total (ug Mn/L)	12	65	18.5%	Jun-96	Feb-04	2.9	241	36.52	-
		pH (Standard Units)	24	71	33.8%	Jun-96	Feb-04	6	8.46	6.74	+
WQN0137	BRODHEAD CREEK, SR2028 BR	Fecal Coliform (CFU/100mL)	77	121	63.6%	Jan-90	Feb-02	20	35000	1751	-
		pH (Standard Units)	1	46	2.2%	Oct-98	Feb-04	6.3	8.55	7.09	+
		Phosphorus, Total (mg P/L)	70	144	48.6%	Jan-90	Feb-04	0.019	0.64	0.11	-
WQN0139	BUSHKILL CREEK-T523 BR	Fecal Coliform (CFU/100mL)	2	22	9.1%	Oct-98	Feb-02	10	720	85	-
		pH (Standard Units)	50	147	34.0%	Jan-90	Dec-03	5.8	8.2	6.52	NA
WQN0176	DELAWARE R., SR0080 BR, DEL WTR GAP	Fecal Coliform (CFU/100mL)	11	72	15.3%	Jan-90	Jan-96	10	1400	120	-
		Manganese, Total (ug Mn/L)	9	71	12.7%	Jan-90	Jan-96	10	172	33	+
		pH (Standard Units)	11	71	15.5%	Jan-90	Jan-96	6.1	7.8	6.73	-
WQN0181	LITTLE BUSHKILL CREEK, T305 BR	pH (Standard Units)	136	201	67.7%	Jan-90	Jul-98	5.3	7.2	6.33	-
WQN0192	ADAMS CREEK	pH (Standard Units)	17	56	30.4%	Nov-00	Mar-04	5.83	7.49	6.74	+

Notes: 1) “Violations” refers to the number of times observed values exceeded the threshold criteria used for any given parameter.
2) For “Trend”, a “+” indicates an upward trend in observed concentrations or counts, and “-“ indicates a downward trend, and “NA” indicates no obvious trend.

Currently, the PA DEP has a list of TMDLs to be completed by 2007 posted on their web site (http://www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/TMDL/TMDL_6yearplan.pdf). Neither the Delaware River, nor any of the impaired Pennsylvania tributaries are listed in this report. Therefore, it is estimated that the TMDLs affecting the DEWA property will be conducted after the 2007 round has been completed. The NJ DEP listed the impaired waters within the DEWA property during 2002. The NJ DEP has published a list of TMDLs to be completed by the end of 2006 (http://www.state.nj.us/dep/wmm/sgwqt/wat/integratedlist/2006TMDLsched.pdf). This list does not include any of the impaired water bodies within the DEWA property. Therefore, an estimate of 2007-2010 seems appropriate for TMDL assessment of these water bodies.

Figure 5. Location of all water quality monitoring stations, and stations that exceeded the established water quality criteria.

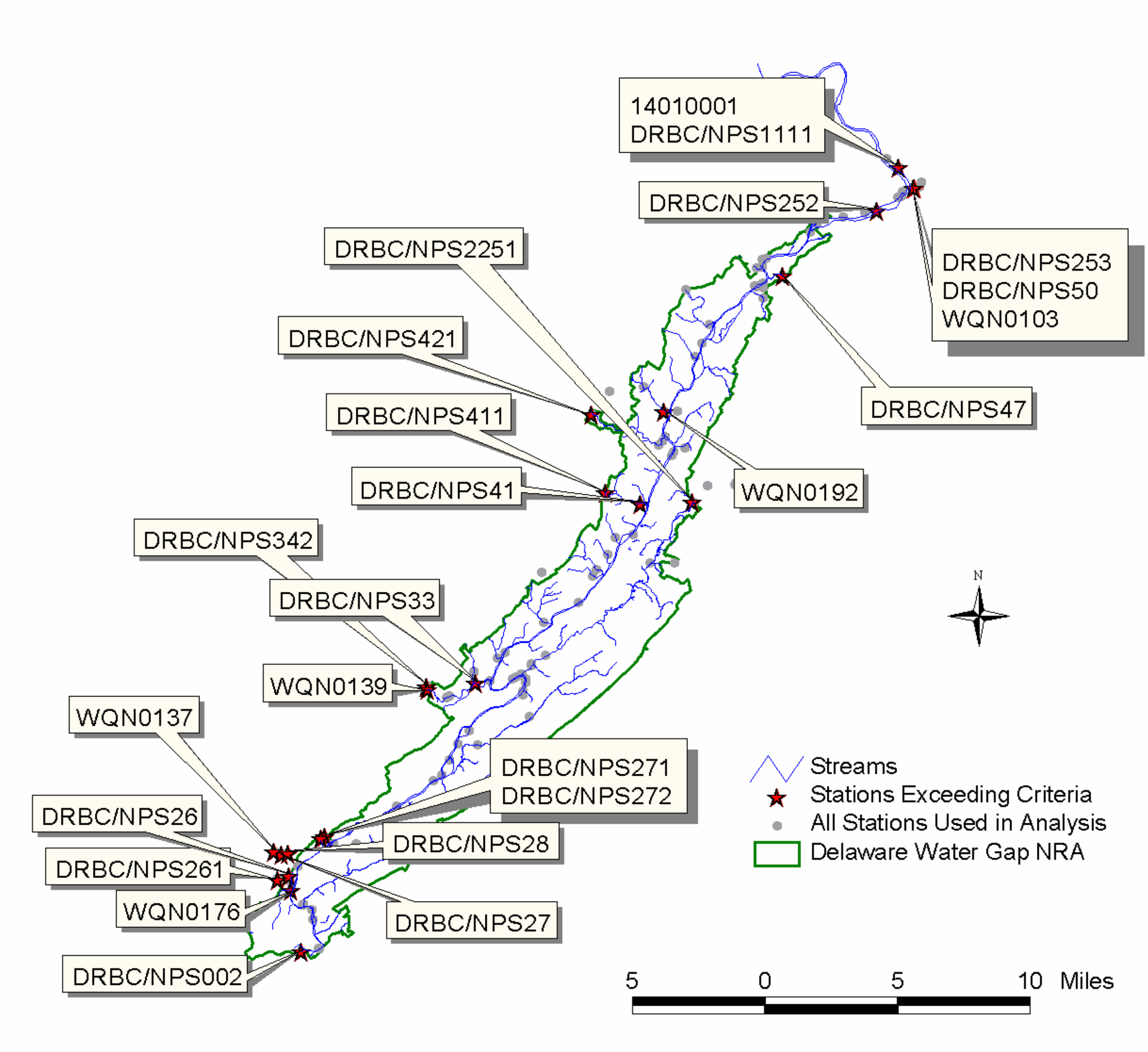


Table 4. Estimated and threshold loading rates (in kg/ha per year).

<table>
<tr><th rowspan="2">USGS Gage</th><th rowspan="2">WQ Station</th><th rowspan="2">Area (HA)</th><th colspan="3">Mean Annual Load (kg/HA/yr)</th></tr>
<tr><th>TSS</th><th>TN</th><th>TP</th></tr>
<tr><td colspan="3">Threshold Value</td><td>785.3</td><td>8.6</td><td>0.30</td></tr>
<tr><td rowspan="5">1434000</td><td>DRBC/NPS110</td><td rowspan="5">797,749</td><td rowspan="5">258.9</td><td rowspan="5">1.7</td><td rowspan="5">0.15</td></tr>
<tr><td>DRBC/NPS1111</td></tr>
<tr><td>14010001</td></tr>
<tr><td>WQN0103</td></tr>
<tr><td>DRBC/NPS109</td></tr>
<tr><td rowspan="2">1438500</td><td>DRBC/NPS461</td><td rowspan="2">901,513</td><td rowspan="2">-</td><td rowspan="2">2.7</td><td rowspan="2">-</td></tr>
<tr><td>5700024700</td></tr>
<tr><td rowspan="3">1439500</td><td>WQN0139</td><td rowspan="3">30,576</td><td rowspan="3">307.8</td><td rowspan="3">2.6</td><td rowspan="3">0.20</td></tr>
<tr><td>DRBC/NPS341</td></tr>
<tr><td>DRBC/NPS333</td></tr>
<tr><td rowspan="2">1440000</td><td>DRBC/NPS32</td><td rowspan="2">17,142</td><td rowspan="2">-</td><td rowspan="2">2.5</td><td rowspan="2">0.14</td></tr>
<tr><td>9376000115</td></tr>
<tr><td rowspan="2">1440200</td><td>DRBC/NPS3</td><td rowspan="2">992,802</td><td rowspan="2">-</td><td rowspan="2">2.9</td><td rowspan="2">0.28</td></tr>
<tr><td>DRBC/NPS2</td></tr>
<tr><td rowspan="2">1442500</td><td>WQN0137</td><td rowspan="2">66,020</td><td rowspan="2">-</td><td rowspan="2">2.8</td><td rowspan="2">0.29</td></tr>
<tr><td>DRBC/NPS27</td></tr>
<tr><td>1446500</td><td>None</td><td>1132591.2</td><td>-</td><td>-</td><td>-</td></tr>
</table>

Presence of Existing Gages and Monitoring Sites

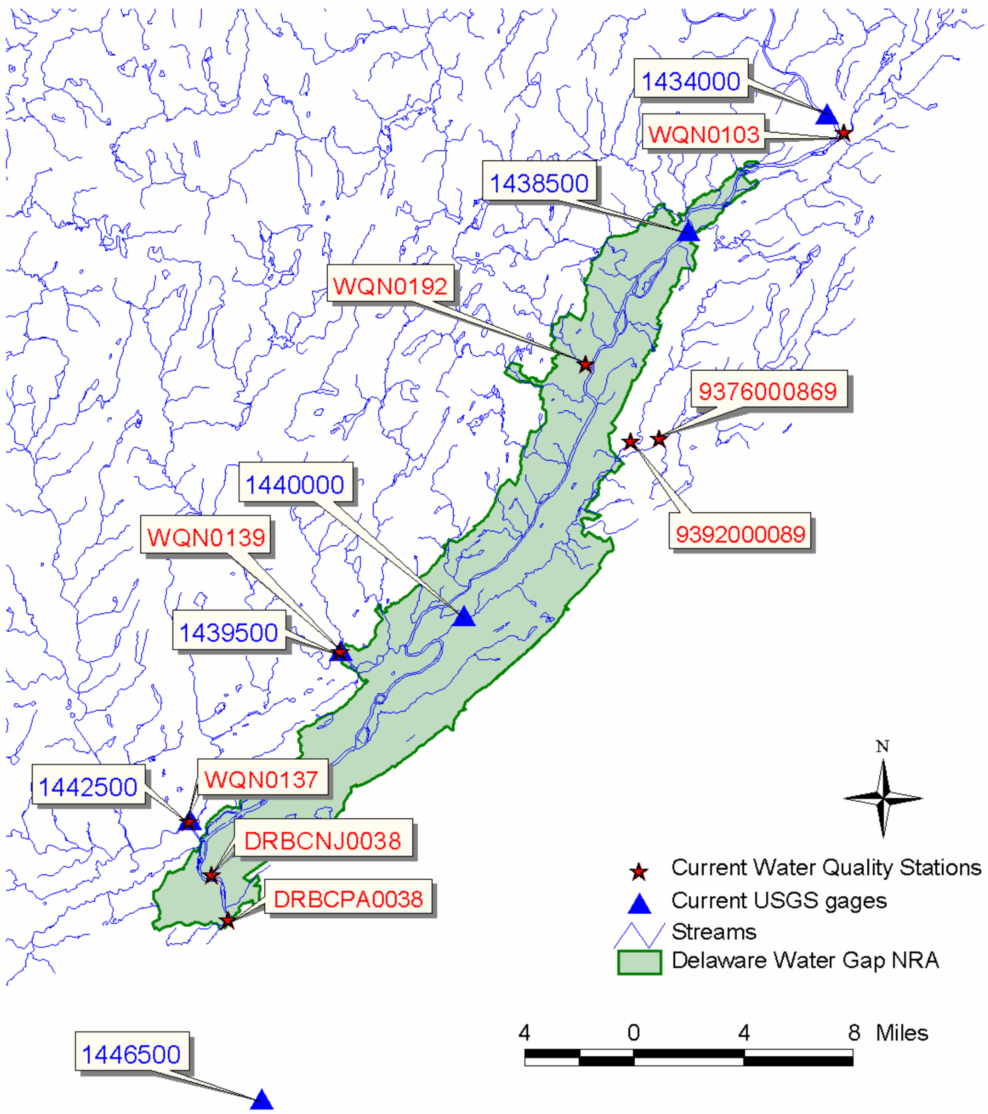
At present, there are six active USGS stream flow gages in and around the Delaware Water Gap NRA (Figures 3 and 9). USGS stream flow gage 1440200, used in previous sections of this report, was discontinued in January 1996. Data from all of these gages were used in the loading rate calculations described in the previous section. Descriptive information pertaining to all six gages is presented in Table 5.

With respect to water quality monitoring stations, there are 8 stations relevant to DEWA water quality that appear to be actively compiling data in the Modern STORET database. The name and location of each of these stations is depicted in figure 6. Based on a review of recently recorded STORET data, the stations maintained by the Pennsylvania DEP (Stations beginning with "WQN") have the most detailed and complete chemistry data. These stations are collecting a fairly complete suite of metals, nutrients, and basic water quality parameter data on a monthly basis. The remaining four stations have a limited and infrequent amount of basic chemical data (i.e. pH, temperature, etc.).

Table 5. Active USGS stream gages.

USGS Site Number	Location
1442500	Brodhead Creek at Minisink Hills, PA
1439500	Bush Kill at Shoemakers, PA
1440000	Flat Brook near Flatbrookville, NJ
1438500	Delaware River at Montague, NJ
1434000	Delaware River at Port Jervis, NY
1446500	Delaware River at Belvidere, NJ

Figure 6. Active USGS stream discharge gages, and STORET water quality monitoring stations.



In addition to the long-term station described data available through the USGS and the UPEPA, the DRBC and NPS have been collecting data at an additional 7 sites on the Delaware river mainstem in support of the 'special protection waters' designation. These sites are located at Port Jervis, DEWA northern boundary, Milford Access, Dingmans Access, Bushkill Access, Smithfield Access, and Kittatinny Point. Data collected at these sites include air and water temperature, dissolved oxygen, pH, specific conductivity, turbidity, and fecal coliform count. Between 1990 and 1993, nitrogen and phosphorus species, biochemical oxygen demand, and dissolved and suspended solids also measured. From the late 1980's through 1993, these sites were monitored bi-weekly between May and September. Since 1994 sampling has been conducted once per month throughout the entire year, following a redesigned monitoring strategy (DRBC, 1995).

Currently, the USGS and the NPS are completing the third of a three-year intensive investigation of tributary water quality within DEWA. Water samples are currently being collected from Bushkill and Little Bushkill Creeks, Sand Hill Creek, Toms Creek, Hornbecks Creek, Dingmans Creek, Adams Creek, Raymondskill Creek, Sawkill Creek, Vandermark Creek, Shimers Brook, Big and Little Flatbrook, and VanCampens Brook. The samples from each of these watersheds are being analyzed for an extensive array of metals, nutrients, and physical and biological water quality parameters. The purpose of this study is to establish baseline water quality conditions for these tributaries as part of the DRBC/NPS special protection regulations stating that "there be no measurable change in existing water quality except towards natural conditions". Though the information is not currently available through STORET, it is likely that the data will be uploaded to the system upon completion of the study.

Recommendations for Future Monitoring

Based on the analyses presented above, it appears that problems related to phosphorus pollution, pH, and bacterial contamination (and potentially other constituents listed in the 303d table) are affecting water quality, at least to a limited extent within Delaware Water Gap NRA surface waters.

As can be concluded by comparing Legacy STORET and Modern STORET query results for the DEWA region, many stations that historically were used to monitor the Delaware River watershed have been discontinued. It will be necessary to re-establish stations in several key drainage basins in order to properly assess nutrient, bacteria, metals, organic constituent, and pH conditions in preparation for upcoming TMDL assessments. As discussed in a previous section, the New Jersey and Pennsylvania Departments of Environmental Protection are planning to conduct the required TMDLs for 303-listed waters in the Delaware River watershed in the near future. In anticipation of this, the respective agencies will be collecting data (at least on a short-term basis) on all impaired waters. While plans for data collection by these departments have not been officially announced, it may be beneficial for park managers to contact the state agencies in the near future regarding this issue.

From an ecological monitoring perspective, it would be beneficial for the NPS to set up long-term discharge and chemical monitoring stations on several of the watersheds within the DEWA property. These watersheds include VanCampens Brook, Tom's Creek (this may be of specific interest because of the watershed's 'Exceptional Value' designation), Dingmans Creek, Raymondskill Creek, and Sawkill Creek. Each of these watersheds is included in the current USGS/NPS investigation of DEWA tributaries discussed above. Therefore, a good strategy would be to continue monitoring (based on specific results) at the sites established for this study. A stream discharge monitoring station could be co-located with WQN0192 to provide further information on the condition of the Adam's Creek watershed. Additionally, several long-term stream discharge sites do not currently have co-located water quality stations. The stations include USGS gages 1438500 and 1440000. Chemistry data collected at gage 1440000 would be particularly useful because the gage is located on Flat Brook, which is slated for a TMDL. As previously mentioned, co-located chemistry and flow stations provide the ability to investigate pollutant loads, as well as chemical concentrations. The extent to which these recommendations are followed will largely depend upon funding considerations. Therefore, input from state Departments of Environmental Protection and the USGS will undoubtedly prove useful in the decision making process.

Literature Cited

Delaware River Basin Commission. 1996. Administrative Manual part III: Water Quality Regulations. Delaware River Basin Commission, West Trenton, NJ. 104pp.

Delaware River Basin Commission and National Park Service. 1995. Redesign of the DRBC/NPS Scenic Rivers Monitoring Program. Report no. 18 of the DRBC/NPS Cooperative Monitoring Program. 70pp.

National Park Service. 1995. Baseline Water Quality Data Inventory and Analysis: Delaware Water Gap National Recreation Area and Upper Delaware Scenic and Recreational River, Tech. Report NPS/NRWRD/NRTR-95/42, 1403 pp.

NJDEP (New Jersey Department of Environmental Protection), 2004. State of New Jersey's 2004 Integrated Water Quality Monitoring and Assessment Report: Appendix 1C TMDLs or other responses to be completed by 2006. http://www.state.nj.us/dep/wmm/sgwqt/wat/integratedlist/2006TMDLsched.pdf (Last accessed September 27, 2004).

PADEP (Pennsylvania Department of Environmental Protection), 2004. Pennsylvania DEP's Six Year Plan for TMDL Development. http://www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/TMDL/TMDL_6yearplan.pdf (Last accessed September 27, 2004).

Sheeder, S. A. and B.M. Evans, 2004. Estimating Nutrient and Sediment Threshold Criteria for Biological Impairment in Pennsylvania Watersheds. Journal of the American Water Resources Association (JAWRA) 40(4): 881-888.

USEPA (U.S. Environmental Protection Agency), 2002a. List of Drinking Water Contaminants & MCLs. EPA 816-F-02-013, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2002b. Implementation Guidance for Ambient Water Quality Criteria for Bacteria. EPA-823-B-02-003, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2002c. National Recommended Water Quality Criteria: 2002. EPA-822-R-02-047, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 1986. Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003, U.S. Environmental Protection Agency, Washington, D.C.

WATER QUALITY SUMMARY

for

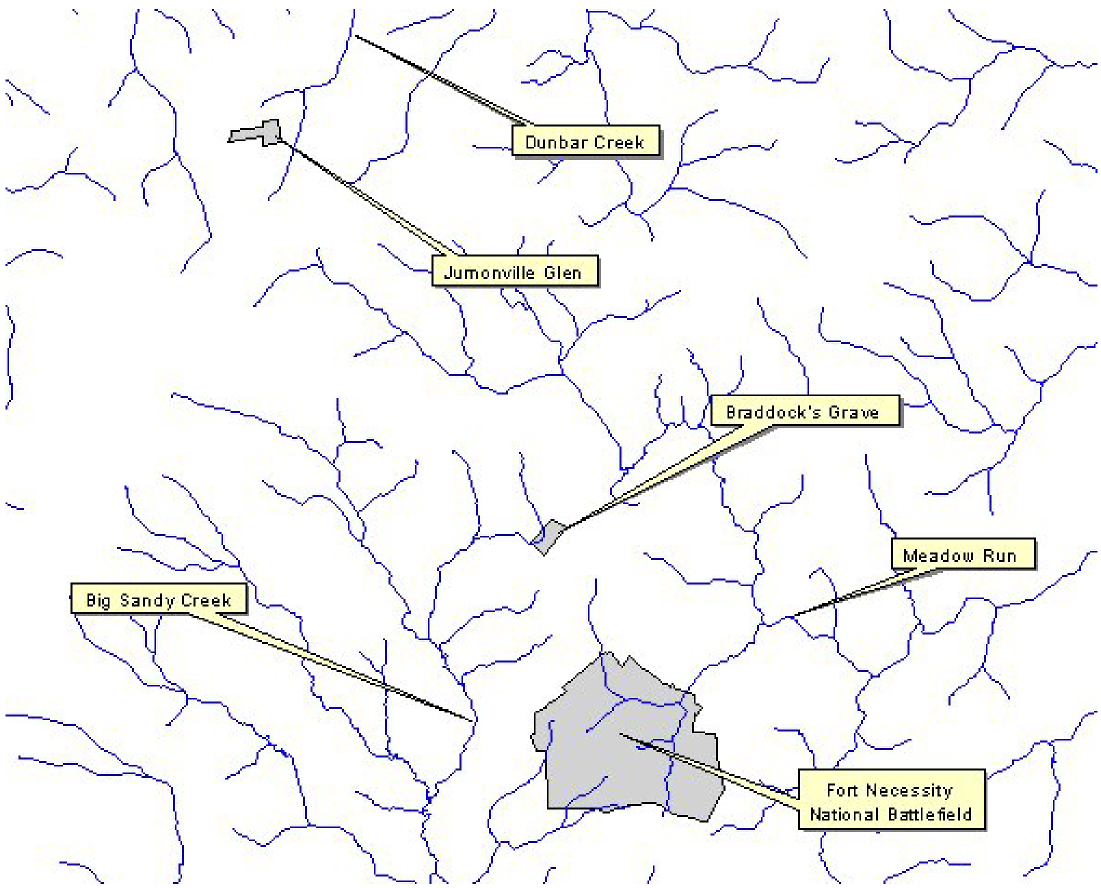
FORT NECESSITY NATIONAL BATTLEFIELD

September 2004

Overview of Park/Watershed Characteristics

The Fort Necessity National Battlefield (FONE) park is actually comprised of three separate parcels, including the main park area and the Jumonville Glen and Braddock's Grave units to the north (see Figure 1). The entire site is about 922 acres in size, with the main park area being much larger than the other two. All three sites are primarily forested areas located in the headlands of different sub-watersheds. The Jumonville Glen unit drains to Dunbar Creek; the Braddock's Grave unit drains to Big Sandy Creek; and the main park area drains to both Big Sandy Creek and Meadow Run.

Figure 1. Location of the various park units.



Historical Water Quality Overview

Detailed analyses of water quality within and around FONE, as well as other national parks, has previously been prepared by the Water Resources Division (WRD) of the National Park Service (NPS, 1995). These reports are typically referred to as "Horizon" reports after the contractor that performed most of the analyses (Horizon Systems Corporation). For the area around FONE, the analyses described in the Horizon report were collectively done for the period 1926-1994 using data for a total of 47 water quality monitoring stations (both active and inactive) in and around the three park units. It should be noted here, however, that most of the stations reported on are located on streams that do not flow through the park or do not contribute any flow or loads to any of the park areas. Therefore, most of the results presented in the earlier report (and summarized below) may not be relevant with respect to water quality issues facing this particular park.

In the Horizon report, it was noted that during the 1926-1994 period, stream observations for a total of 14 parameters exceeded the screening criteria used in the study at least once within the combined study area boundary used (which as noted above, included areas outside any of the park units). These parameters included dissolved oxygen, pH, turbidity, bacteria (total coliform and fecal coliform), cyanide, sulfate, arsenic, beryllium, cadmium, copper, lead, nickel, selenium, silver, and zinc. The criteria used for various parameters included EPA criteria for the protection of freshwater aquatic life and drinking water, and WRD screening limits for freshwater bathing. Based on the results of this study, it was believed by the authors that surface waters within sections of the area studied (particularly around Stony Fork) had been impacted by human activities, and that such impacts were primarily due to extensive coal mining (both strip and deep mines), municipal and industrial wastewater discharges, agricultural operations, urban runoff, construction activities, recreational use, and atmospheric deposition. However, given the fact that the assessment was done using some very old monitoring data (i.e., back to 1926 in some cases), it is likely that some of the problems identified have since been rectified (e.g., those related to municipal and industrial discharges), and that other problems related to coal mining have diminished somewhat due to the fact that there are far fewer active mines now than there were during the time period studied. Additionally, most of the problematic water quality stations were located some distance away from any of the park areas on streams such as Big Sandy Creek and Stony Fork.

Many of the contaminant exceedances described above are probably not particularly important today either because of very low exceedance percentages (e.g., 5% of the total observations or less), or because such exceedances occurred over 20 years ago. Based on the above limitations, it appears that the primary parameters of concern now in the areas surrounding the park are pH, cyanide, sulfate, cadmium, copper, nickel, and zinc. These problems, however, are primarily found in areas outside the immediate vicinity of the three park areas such as the Big Sandy Creek and Stony Creek watersheds. Downstream of the main park area, problems have been recorded in the Deadman Creek watershed, and many of the streams in this specific watershed have been 303d-listed by the Pennsylvania DEP for problems related to runoff and siltation from small residential areas.

Specially Designated Surface Water Bodies

As depicted in Figure 2, all of the streams that run through the main park area and the Braddock's Grave unit (approximately 3.72 miles of streams) have been designated as "high quality" streams. Table 2 provides descriptions of stream uses as defined by the Pennsylvania DEP.

Figure 2. Location of designated high quality streams within the park.

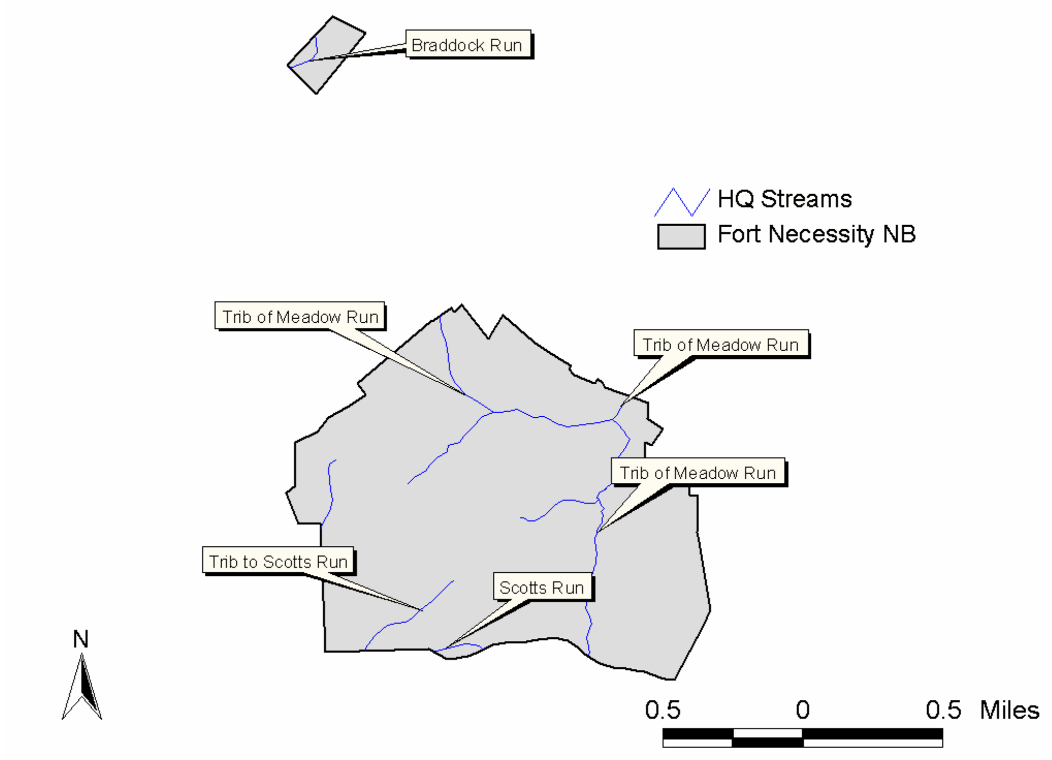


Table 2. Descriptions of designated water uses in Pennsylvania.

Protected Water Uses in Pennsylvania
CWF - *Cold Water Fishes* - Maintenance or propagation, or both, of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat
WWF - *Warm Water Fishes* - Maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat
MF - *Migratory Fishes* - Passage, maintenance and propagation of anadromous and catadromous fishes and other fishes which ascend to flowing waters to complete their life cycle.
TSF - *Trout Stocking* - Maintenance of stocked trout from February 15 to July 31 and maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
HQ - *High Quality Waters* - Surface waters having quality which exceeds levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water by satisfying § 93.4b(a). **EV** - *Exceptional Value Waters* - Surface waters of high quality which satisfy § 93.4b(b) (relating to antidegradation).

Current Listing of Water Quality Impairments

There are no surface water bodies contained within any part of the park that are currently included on Pennsylvania's 303d list of impaired water bodies.

Current Water Quality Trends

As was done with the other parks in the ERMN region, an attempt was made to evaluate more recently compiled water quality data to assess whether potential problems identified in the past still exist. Unfortunately, there were no water quality stations near any of the Fort Necessity park units for which data beyond the early 1990s were available for analysis.

TMDL Development

The Pennsylvania Department of Environment Protection (DEP) is the agency responsible for conducting total maximum daily load (TMDL) assessments for impaired waters in the Commonwealth of Pennsylvania. A TMDL is essentially a plan of action used to clean up streams that are not meeting water quality standards. The plan includes pollution source identification and strategy development for contaminant source reduction or elimination. As of the date of this document (September 2004), no water bodies within the FONE park boundary have been identified as requiring a TMDL.

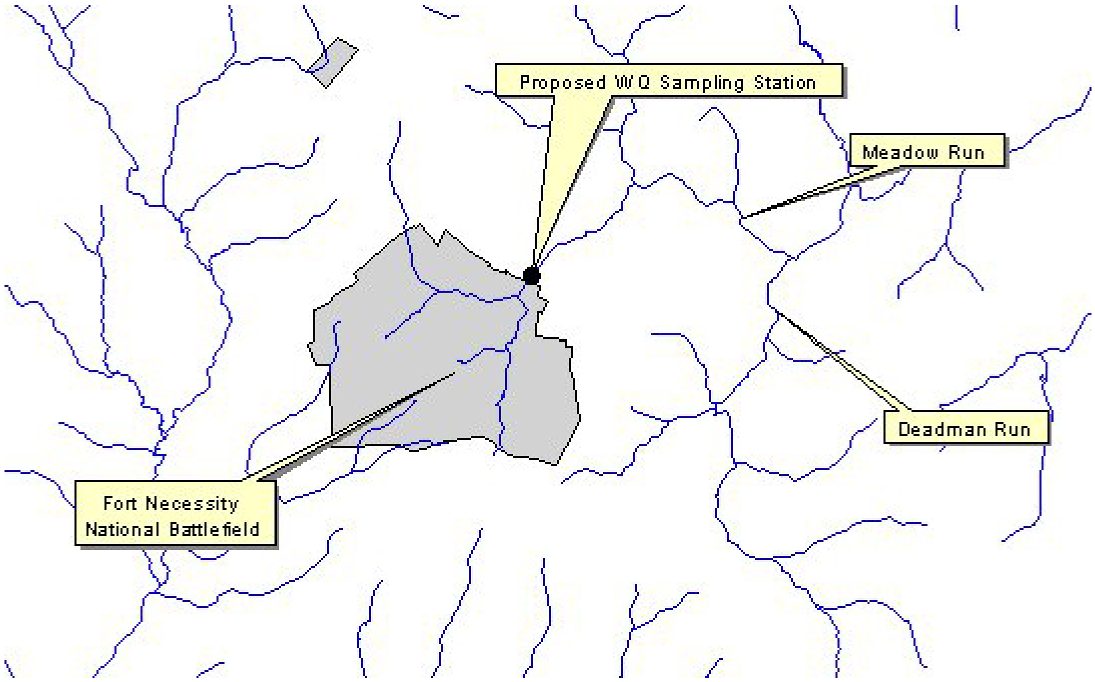
Presence of Water Quality Monitoring Sites

At present, there are no long-term water quality monitoring stations located in, or in the immediate vicinity of, the park.

Recommendations for Future Monitoring

Based on the results of the Horizon report, and the fact that no streams within the park have been 303d-listed, it does not appear that there are currently any water quality problems within the park. However, in the Horizon report, it was noted that in-stream zinc concentrations within Meadow Run exceeded the acute freshwater criterion of 120 µg/L from 1974 through 1994 at the confluence of this stream and Deadman Run (see Figure 3). For this reason, it is recommended that a limited amount of sampling be conducted on the tributary stream that exits the main park area (also shown in Figure 3). In addition to zinc, other "Level 1" parameters such as alkalinity, pH, specific conductivity, dissolved oxygen, temperature, instantaneous stream discharge, nutrients (N and P), turbidity, and fecal coliform should also be collected for the purpose of assessing potential water quality problems associated with this section of the park.

Figure 3. Location of streams and proposed sampling site.



Literature Cited

National Park Service. 1997. Baseline Water Quality Data Inventory and Analysis: Fort Necessity National Battlefield, Tech. Report NPS/NRWRD/NRTR-97/131, 499 pp.

Sheeder, S. A. and B.M. Evans, 2004. Estimating Nutrient and Sediment Threshold Criteria for Biological Impairment in Pennsylvania Watersheds. Journal of the American Water Resources Association (JAWRA) 40(4): 881-888.

USEPA (U.S. Environmental Protection Agency), 2002a. List of Drinking Water Contaminants & MCLs. EPA 816-F-02-013, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2002b. Implementation Guidance for Ambient Water Quality Criteria for Bacteria. EPA-823-B-02-003, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2002c. National Recommended Water Quality Criteria: 2002. EPA-822-R-02-047, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 1986. Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003, U.S. Environmental Protection Agency, Washington, D.C.

WATER QUALITY SUMMARY

for

FRIENDSHIP HILL NATIONAL HISTORIC SITE

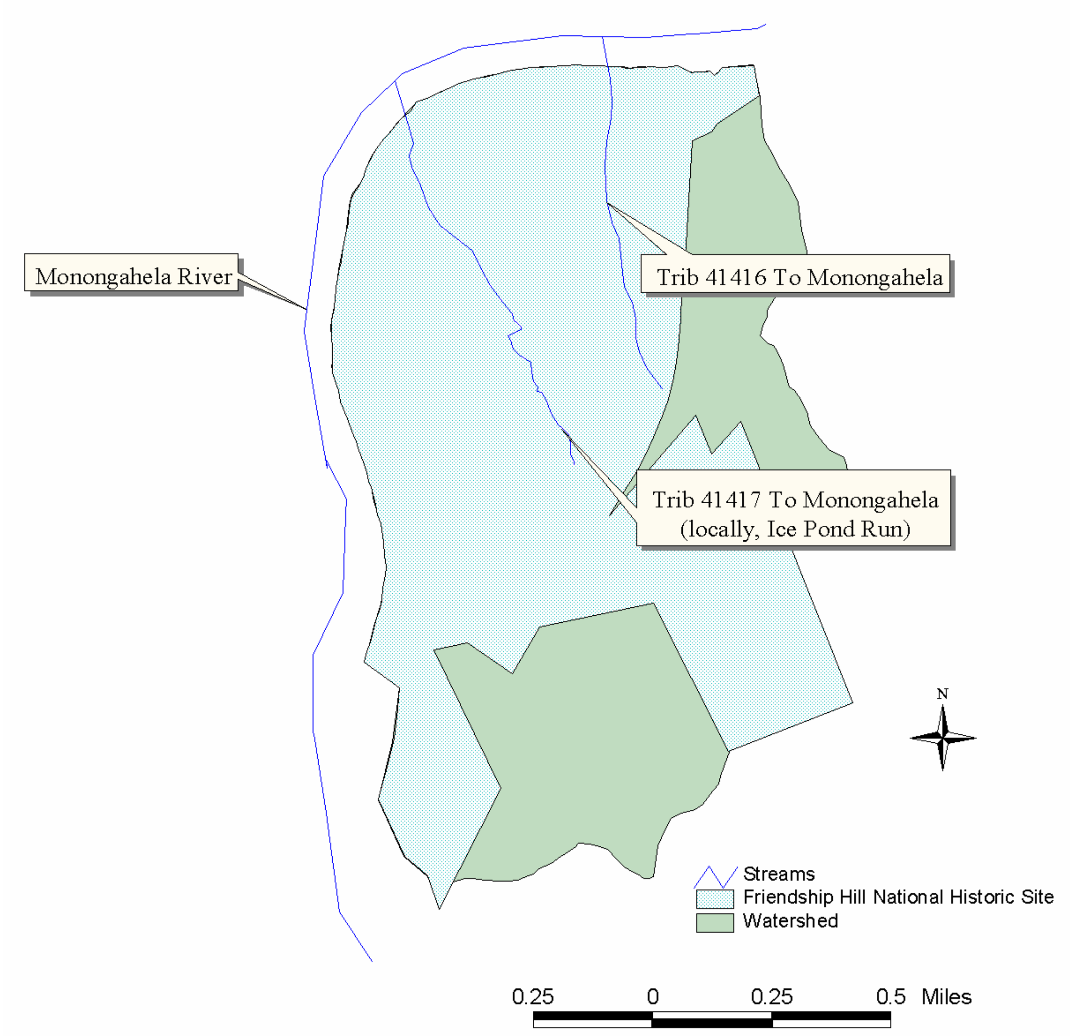
September 2004

Overview of Park/Watershed Characteristics

The Friendship Hill National Historic Site (FRHI) is approximately 659 acres (1.0 mi^2) in size, and is almost entirely forested with small amounts of grassland / row crop / agricultural land distributed throughout the park. The watershed is 917 acres (1.4 mi^2) in size. The land use/cover within this watershed is similar to land cover within the park boundary

The watershed within which the park is located, streams, and the FRHI boundary are depicted in Figure 1. As can be seen in this figure, there are two streams that flow through FRHI. Both of these streams are unnamed tributaries (Tributary 41417 is locally known as 'Ice Pond Run') of the Monongahela River which borders the park property on the western and northern boundaries. There are no USGS stream discharge monitoring stations located within the FRHI watershed. Therefore, no estimates of stream discharge or pollutant load (calculated as discharge x concentration) can be made.

Figure 1. Location of park, watershed and streams within Friendship Hill National Historic Site.



Historical Water Quality Overview

Detailed analyses of water quality within and around FRHI, as well as other national parks, has previously been prepared by the Water Resources Division (WRD) of the National Park Service (NPS, 1995). These reports are commonly referred to as "Horizon" reports after the contractor that performed most of the analyses (Horizon Systems). A Horizon report was completed for FRHI using data collected between 1949 and 1997 at sites located within a region extending three miles upstream and one mile downstream of the park boundary. Based upon these temporal and spatial criteria, data from 113 water chemistry sampling stations, 10 stream discharge gaging stations, and 51 industrial/municipal dischargers were retrieved from a variety of federal and state sources (EPA, USGS, PADEP, etc.). It should be noted here, however, that due to the method of study area delineation, the location of the FRHI property (adjacent to the Monongahela River), and the temporal extent of the data used in the analysis, some of the results presented in the earlier report (and summarized below) may not be relevant with respect to water quality issues currently facing FRHI. That is, almost all of the stations reported on are located on streams that do not flow through the parks or do not contribute any flow or loads to either park area.

In the Horizon report, it was noted that 21 different water quality parameters exceeded the screening criteria used in the study at least once within the study area. Antimony, beryllium, cadmium, carbon tetrachloride, chloride, chlorine, coliform bacteria (total and fecal) concentrations, copper, cyanide, dissolved oxygen, fluoride, lead, nickel, nitrate, nitrite plus nitrate, pH, phenanthrene, sulfate, turbidity, and zinc each exceeded one or more of the screening criteria. Screening limits used include the WRD primary body contact recreation and aquatic life criteria, EPA drinking water criteria, and EPA criteria for the protection of freshwater aquatic life.

Based on the results of this study, it was believed by the authors that surface waters within the study area have been greatly impacted by human activities. The authors concluded that aquatic degradation could principally be attributed to acid mine drainage from active and abandoned coal mines, gas and oil extraction, industrial and municipal discharges, stormwater runoff, agricultural activities, and atmospheric deposition.

Many of the contaminant exceedances described above may not be particularly relevant today either because of very low exceedance percentages (less than 10% for many of the chemical constituents), because such exceedances occurred over 20 years ago, or because exceedances were identified at stations having little or no effect on NPS park property (This is the case with many of the Monongahela River sampling sites). Based on the above limitations, it appears that the primary pollutants of present concern include pH, cadmium, nickel, beryllium and sulfate.

Specially Designated Surface Water Bodies

According to the Pennsylvania surface water file (this is the file used for 303d, water use designation, etc.), there are 1.7 miles of streams located within the FRHI park boundary that have a designated use and/or anti-degradation policy associated with the water body. These Streams are depicted in Figure 1.

Both of the streams that flow through FRHI are designated as 'warm water fishery' streams. According to the Pennsylvania stream designation system, warm water fishery streams are afforded the lowest available level of protection. Table 1 provides information on the different Pennsylvania surface water designations. Further detail on these policies can be found in Title 25, Chapter 93 of the Pennsylvania Code.

Table 1. Descriptions of designated water uses in Pennsylvania.

CWF - *Cold Water Fishes* - Maintenance or propagation, or both, of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat

WWF - *Warm Water Fishes* - Maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat

MF - *Migratory Fishes* - Passage, maintenance and propagation of anadromous and catadromous fishes and other fishes which ascend to flowing waters to complete their life cycle.

TSF - *Trout Stocking* - Maintenance of stocked trout from February 15 to July 31 and maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.

HQ - *High Quality Waters* - Surface waters having quality which exceeds levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water by satisfying § 93.4b(a).
EV - *Exceptional Value Waters* - Surface waters of high quality which satisfy § 93.4b(b) (relating to antidegradation).

Current Listing of Water Quality Impairments

As of the date of this report (September 2004), the two streams that are within the park boundary have not been assessed for impairment. Therefore, there are no surface water bodies contained within the FRHI boundary that are currently included on Pennsylvania's 2004 303d list of impaired water bodies.

Current Water Quality Trends

As was done with the other parks in the ERMN region, an attempt was made to evaluate more recently compiled water quality data to assess whether potential problems identified in the past still exist. These selected parameters were based on various factors, including past problems described in the Horizon report, problems identified in 303d listings of waterbodies in Pennsylvania, and the list of core parameters to be used as "vital sign" indicators as identified by the NPS Water Resources Division. Temperature is also listed as one of the core parameters, but was not included here for several reasons. First, there are no established temperature criteria to use to evaluate the condition of the aquatic system. Secondly, trends in temperature could be evaluated but the results may prove misleading due to natural long-term air temperature trends and the relationship between air and water temperature (i.e. gradual warming of mean annual water temperature may reflect recent warming of the climate, and not watershed disturbance).

The 1990 – 2004 water quality data for total nitrogen, total phosphorus, specific conductivity, pH, fecal coliform, mercury, iron, aluminum, manganese, and dissolved oxygen were compared to the chemical criteria provided below. These parameters were selected because they are commonly used to assess certain aspects of the hydrologic system, and are briefly discussed below. For this analysis, all stations for which data were compiled, and those stations that exceeded the water quality criteria outlined below, are shown in Figure 2. The results of the water chemistry analysis (stations / parameters that exceeded the screening criteria) are provided in table 2.

Specific Conductivity is the ability of a substance to conduct an electrical current across a given length at a specified temperature. Specific Conductivity can be used as an indicator of water quality because pure water has a very low electrical conductance. As concentrations of different ions dissolved in water increase, so does the conductivity. Therefore, conductivity is directly related to the amount of charged particles (i.e. heavy metals, clay particles, etc.) contained within a water sample. While there are no set conductivity criteria for fresh water, specific conductance is linearly related to the concentration of total dissolved solids in a sample. For the purposes of this investigation,

$$0.65*K = S$$

where K is conductance (micromhos) and S is dissolved solids (mg/L). The EPA has a recommended criterion of 500 mg/L for dissolved solids in drinking water (US EPA, 2002a). This corresponds to a specific conductivity of 325 micromhos, given the equation above.

PH is one of the most general indicators of water quality. The natural logarithm of hydrogen ion concentration in solution, pH ranges from 0-14 with 7 being neutral. PH values ranging from approximately 6-8 naturally occur in freshwater aquatic systems. The EPA-established criterion for aquatic life protection includes pH values between 6.5 and 9.0. For the purposes of this investigation, recorded values outside of this range were flagged as an indication of impairment.

Fecal Coliform bacteria levels were used as an indicator of failing sewage treatment facilities or otherwise untreated wastewater upstream of a sampling point. In discussion of indicator bacteria, it should be noted that the EPA recommends the analysis of either E. Coli or enterococci bacteria for this purpose. However, there are very few samples of E. Coli and enterococci bacteria available for assessment of aquatic ecosystem health. Therefore, Fecal Coliform data were examined using an EPA (2002b) established threshold of 200 colony forming units (CFU).

High loads and or concentrations of *Total Nitrogen, Total Phosphorus, and Total Suspended Sediment* are often correlated with excessive fertilization of agricultural land, ineffective agricultural management strategies, high levels of impervious surface area, and other anthropogenic disturbances within the watershed. No nationally recognized criteria exist for these three parameters, so criteria published by Sheeder and Evans (2004) were employed. The criteria were developed for the state of Pennsylvania, and are though to be relatively accurate for regions of New York and West Virginia as well. The criteria for total nitrogen, total phosphorus, and total suspended sediment are 2.01 mg/L, 0.07 mg/L, and 197.27 mg/L respectively.

Elevated concentrations of *Mercury, Iron, Aluminum, and Manganese* and many other metals are commonly associated with large-scale disturbances within a watershed including mining and large-scale construction projects. Elevated metals concentrations can also result from acidic deposition, low watershed acid buffering capacity, and other factors. These four metals were selected from the larger suite of metals associated with mining/disturbance impairments because each has been explicitly implicated as the cause of impairment in section 303d-listed watersheds in Pennsylvania, West Virginia, New York and/or New Jersey. The EPA has published criterion for each of the metals analyzed in this report (USEPA, 2002c). Mercury is designated as a priority pollutant, and has a freshwater CMC criterion of 1.4 ug/l. Iron, Aluminum and Manganese are listed as non-priority pollutants. Iron and Aluminum are assigned freshwater criteria of 1000 ug/L (CCC) and 750 ug/L (CMC), respectively. There is no freshwater criterion set for Manganese. In the absence of an aquatic health criterion, the EPA human health consumption criterion of 50 ug/L was used to define exceedances.

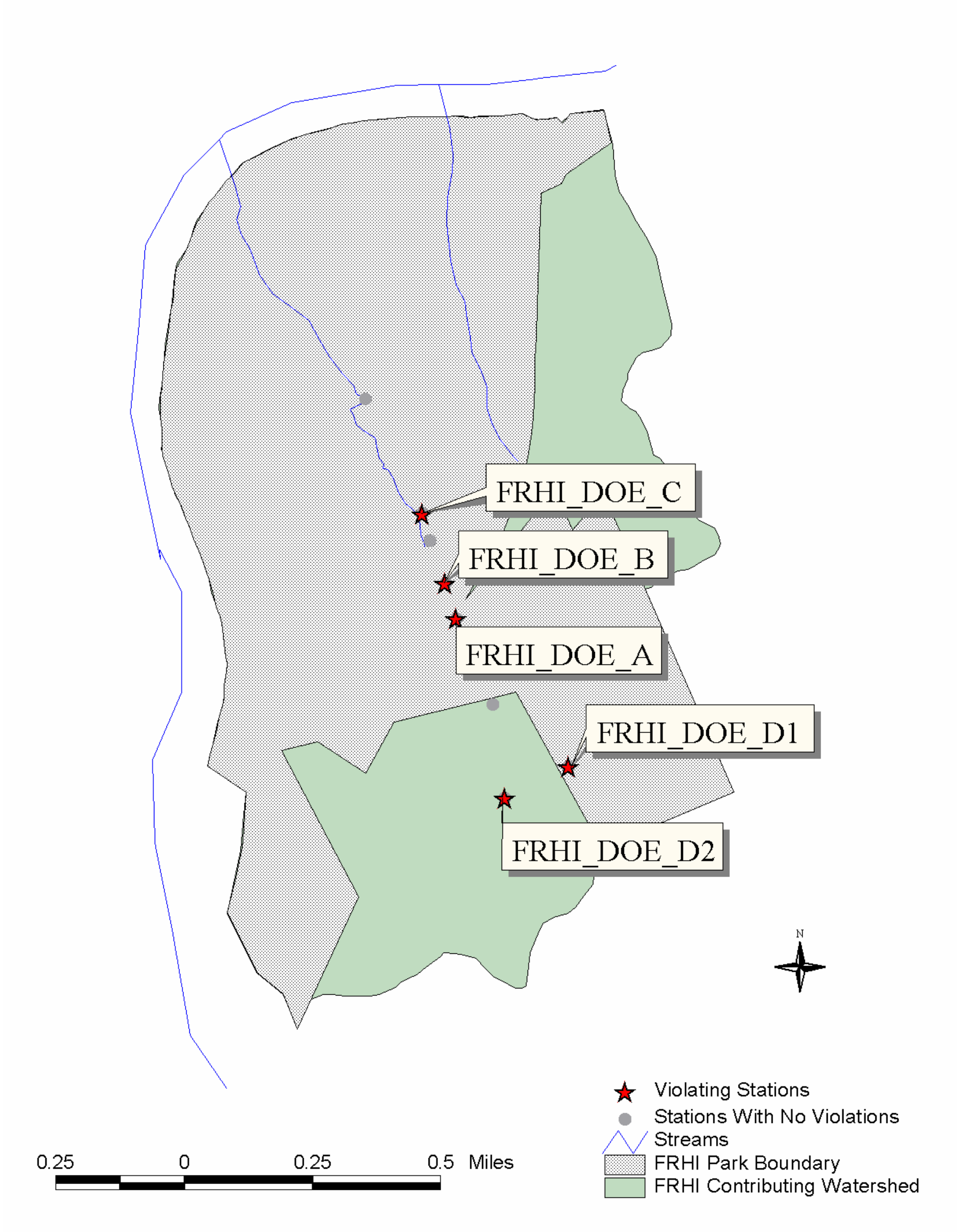
Dissolved Oxygen concentration is the final parameter selected for analysis in this report. Dissolved oxygen concentrations above designated thresholds are essential for the survival of aquatic vertebrates and invertebrates, while low values suggest nuisance algae populations stemming from nutrient pollution. Several different criteria have been specified, due to the varying tolerances of adult and juvenile, warm water and cold water species. For the purposes of this investigation, the one-day minimum, coldwater fishery criterion of 4 mg/L (USEPA, 1986) is employed. This criterion is thought to be the most appropriate because the limit will include all warm water violations, without including samples that would be flagged using the coldwater, juvenile fish criteria (juvenile fish are prevalent during the spring, when mechanical saturation provides sufficient oxygen levels in all but the most impaired watersheds. These watersheds will be identified using the one-day minimum coldwater fishery criteria or via one of the other chemicals).

Results of this analysis (Figure 2 and Table 2) indicate that low pH mine discharge waters, and associated high aluminum concentrations are severe problems at FRHI. The elevated dissolved aluminum concentrations seen at the FRHI water quality stations are lethal to fish species and many other aquatic organisms. Without acid mine drainage and stream discharge information, it is difficult to estimate the extent of impairment in the surface water bodies within the FRHI boundary. However, it is safe to conclude that the streams receiving the mine discharge are biologically impaired and will likely require a further study and remediation work in the future.

Table 2. Results of analyses based on 1990-2004 water quality data at stations in and around FRHI.

Station ID	Station Name	Chemical Characteristic	Number of Exceedances	Sample Count	% Exceedance	Begin Date	End Date	Min. Value	Max. Value	Avg. Value	Trend
FRHI_DOE_A	ICE POND RUN DOWNSTREAM FROM STATE HIGHWAY 166	Aluminum (ug/L)	45	45	100.0%	Jun-91	Jun-96	44,530	83,300	73,098	-
		pH, lab	44	44	100.0%	Jun-91	Nov-94	2.57	2.92	2.81	-
FRHI_DOE_B	ICE POND RUN ADJACENT TO BOM WETLAND	Aluminum (ug/L)	2	2	100.0%	Apr-94	Jun-96	34,820	43,890	39,355	NA
		pH, lab	1	1	100.0%	Apr-94	Apr-94	2.74	2.74	2.74	NA
FRHI_DOE_C	ICE POND RUN DOWNSTREAM FROM BOM WETLAND	Aluminum (ug/L)	5	5	100.0%	Apr-94	Jun-96	23,150	48,050	34,476	NA
		pH, lab	4	4	100.0%	Apr-94	Dec-94	2.65	3.1	3	NA
FRHI_DOE_D1	PRIMARY MINE DRAINAGE TO ICE POND RUN	Aluminum (ug/L)	6	6	100.0%	Jan-90	Jul-93	54,500	73,860	66,643	NA
		pH, lab	6	6	100.0%	Jan-90	Jul-93	2.59	2.74	3	NA
FRHI_DOE_D2	SECONDARY MINE DRAINAGE TO ICE POND RUN	Aluminum (ug/L)	47	47	100.0%	Jun-91	Jul-93	60,300	111,000	87,753	+
		pH, lab	47	47	100.0%	Jun-91	Jul-93	2.41	3.54	2.56	-

Figure 2. Location of all stations used in the analysis, and those stations exceeding one or more of the water chemistry criteria



TMDL Development

The Pennsylvania Department of Environment Protection (DEP) is the agency responsible for conducting total maximum daily load (TMDL) assessments for impaired waters in the Commonwealth of Pennsylvania. A TMDL is essentially a plan of action used to clean up streams that are not meeting water quality standards. The plan includes pollution source identification and strategy development for contaminant source reduction or elimination. As of the date of this document (September 2004), no water bodies within the FRHI park boundary have been identified as requiring a TMDL.

Presence of Water Quality Monitoring Sites

At present, there are no long-term water quality monitoring stations located in, or in the immediate vicinity of, the park.

Recommendations for Future Monitoring

Based on the results of the Horizon report, and the water quality analysis conducted for this report, FRHI surface water bodies are currently affected by water quality problems associated with acid mine discharge. Therefore, it is recommended that sources of acid mine discharge are identified and routinely sampled, along with the receiving water bodies. Additionally, The Pennsylvania DEP is required to survey the streams within FRHI. Therefore, National Park Service employees may wish to contact the PA DEP Office of Water and Wastewater for the most current information regarding the status of assessment, impairment, and/or TMDL preparation.

Literature Cited

National Park Service. 1995. Baseline Water Quality Data Inventory and Analysis: Delaware Water Gap National Recreation Area and Upper Delaware Scenic and Recreational River, Tech. Report NPS/NRWRD/NRTR-95/42, 1403 pp.

Sheeder, S. A. and B.M. Evans, 2004. Estimating Nutrient and Sediment Threshold Criteria for Biological Impairment in Pennsylvania Watersheds. Journal of the American Water Resources Association (JAWRA) 40(4): 881-888.

USEPA (U.S. Environmental Protection Agency), 2002a. List of Drinking Water Contaminants & MCLs. EPA 816-F-02-013, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2002b. Implementation Guidance for Ambient Water Quality Criteria for Bacteria. EPA-823-B-02-003, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2002c. National Recommended Water Quality Criteria: 2002. EPA-822-R-02-047, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 1986. Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003, U.S. Environmental Protection Agency, Washington, D.C.

WATER QUALITY SUMMARY

for

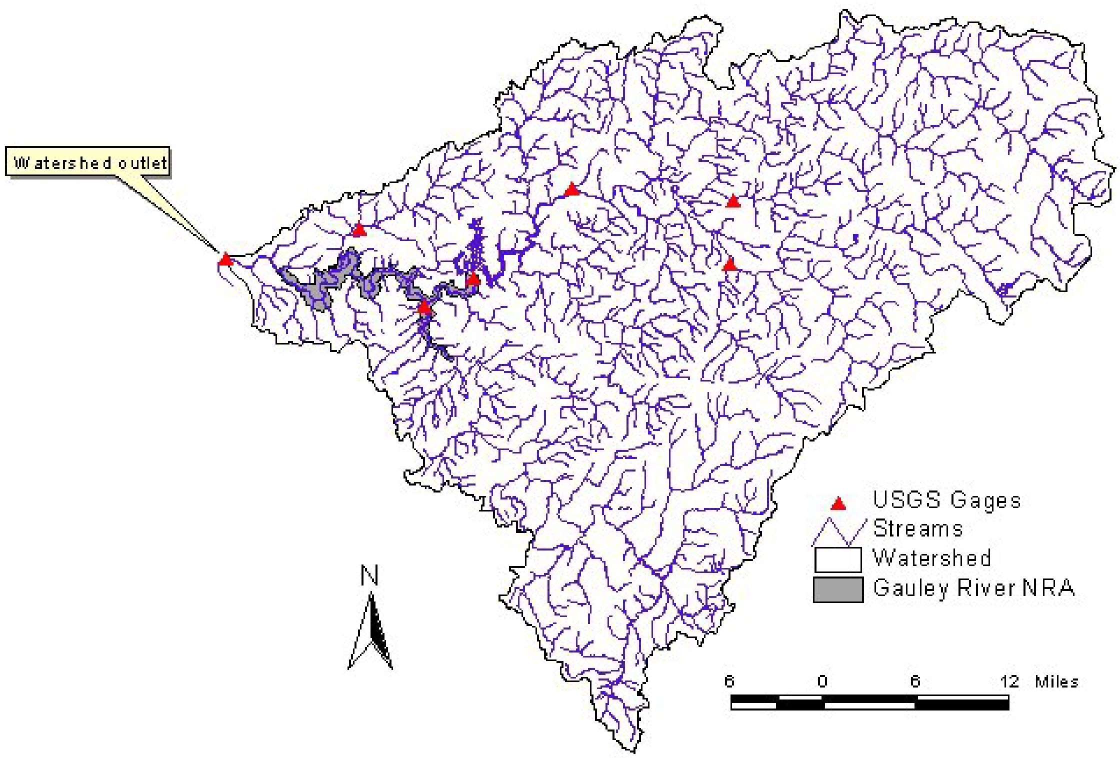
GAULEY RIVER NATIONAL RECREATION AREA

September 2004

Overview of Park/Watershed Characteristics

The park is approximately 11,144 acres (17.4 mi^2) in size, and is comprised almost entirely of woodlands with a very small amount of low-density development (e.g., near the Carnifex Ferry Battlefield State Park), and a small amount of mined land in the downstream portion of the park. The watershed within which the park is located (as defined by a USGS gage located about 3.9 miles downstream of the lowermost edge of the park) is approximately 841,526 acres (1,315 mi^2) in size (see Figure 1). The land use/cover within this watershed is predominantly woodland, with extensive pockets of mined land (especially in the Peter's Creek sub-watershed to the north and in the Beaver Creek and Brushy Fork sub-watersheds to the northeast of the park). One mid-size town (Summersville) is located to the northeast of the park. There is also a limited amount of hay/pasture land in the immediate vicinity of the park.

Figure 1. Location of park, watershed outlet and USGS gages.



As measured at the USGS gage downstream of the park, the mean daily surface water flow on an annual basis within the Gauley River just downstream of the park is about 2778 cfs. Temporal variations in flow on a mean annual basis are depicted in Figure 2. For the purposes of this analysis, various sub-watersheds within the larger watershed have also been defined based on the location of other USGS gages as shown in Figure 3. Table 1 presents information on the relative contributions of each of these smaller sub-watersheds in terms of area and mean annual flows. (These gages are also used in the estimation of nutrient and sediment loading rates as described later in this report). Sub-area 1 is essentially the drainage area for the Meadow River, and Sub-area 2 is the Gauley River drainage area above the dam near Summersville.

Figure 2. Representative mean annual hydrograph of flows by month for the Gauley River below Summersville as derived for a 16-year period (from Gauley River NRA Horizon report).

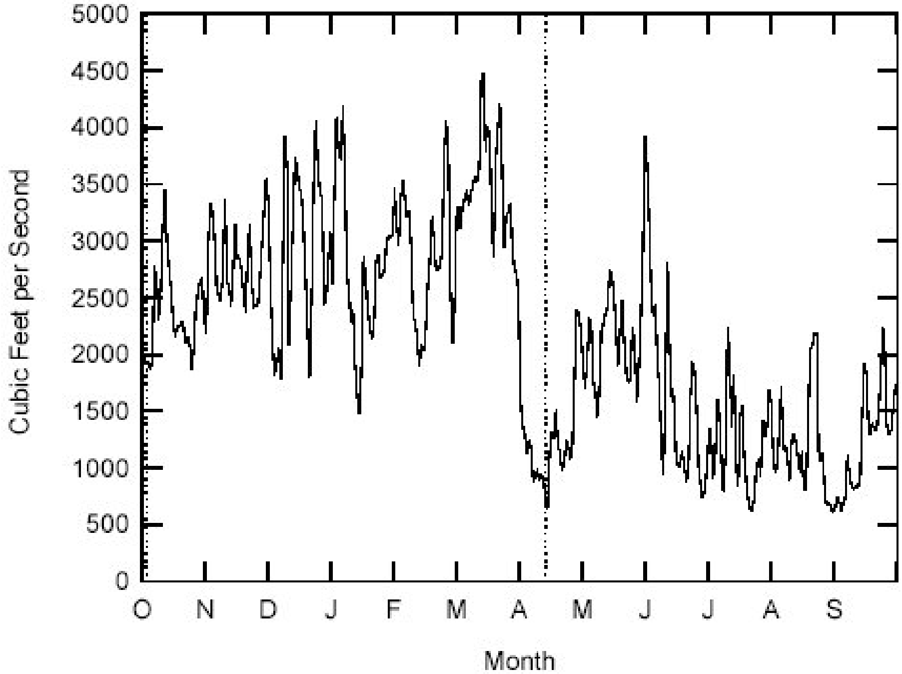


Figure 3. Location of sub-areas with associated USGS gages.

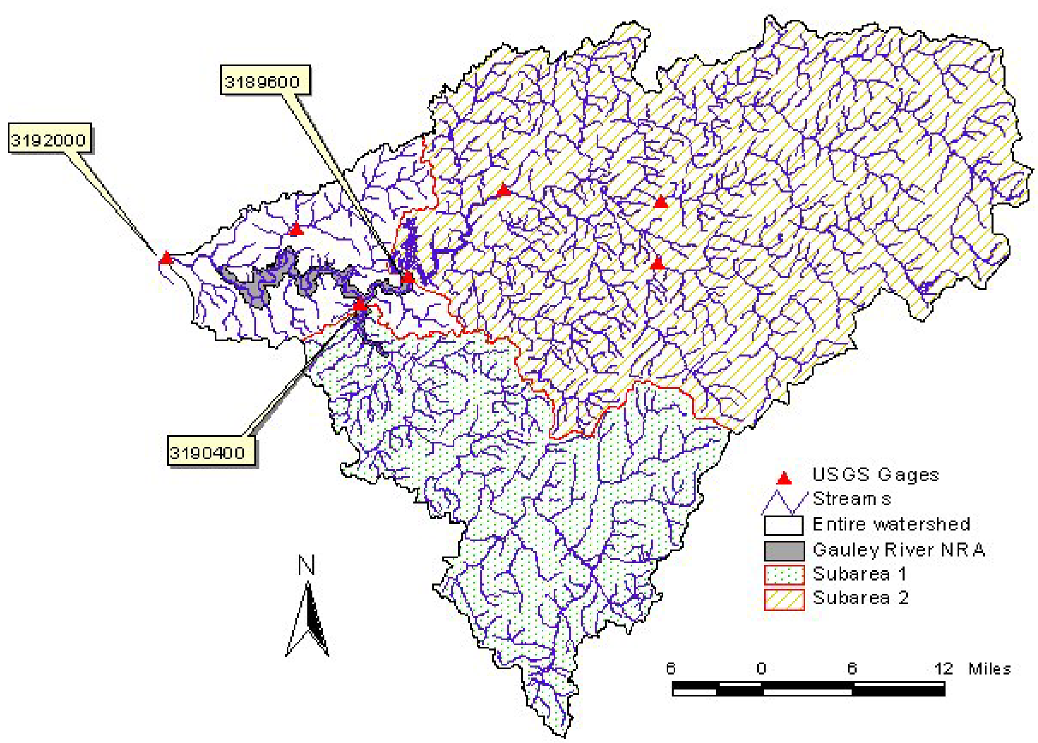


Table 1. Flow characteristics of sub-watersheds.

Watershed	USGS Gage	Mean Daily Flow (cfs)	% of Total Drainage Area	% of Contributed Mean Annual Flow
Entire area	3192000	2778	100	100
Sub-area 1	3190400	732	27.4	26.3
Sub-area 2	3189600	2015	60.3	72.5

Historical Water Quality Overview

Detailed analyses of water quality within and around the Gauley River NRA, as well as other national parks, has previously been prepared by the Water Resources Division (WRD) of the National Park Service (NPS, 1995). These reports are typically referred to as "Horizon" reports after the contractor that performed most of the analyses (Horizon Systems Corporation). For the Gauley River NRA, a Horizon report was done for the period 1946-1995 using data for 80 water quality monitoring stations (both active and inactive) in and around the park. It should be noted here, however, that about 30% of the stations reported on are located on streams that do not flow through the park or do not contribute any flow or loads to the watershed within which the park is located. Therefore, some of the results presented in the earlier report (and summarized below) may not be relevant with respect to water quality issues facing the park.

In the Horizon report, it was noted that during the 1946-1995 period, stream observations for a total of 18 parameters exceeded the screening criteria used in the study at least once within the study area boundary used (which as noted above, was larger than the drainage area for the park). These parameters included dissolved oxygen, pH, antimony, cadmium, chromium, copper, lead, mercury, silver, zinc, beryllium, chloride, nickel, thallium, bacteria (total coliform and fecal coliform), and turbidity. The criteria used for various parameters included EPA criteria for the protection of freshwater aquatic life and drinking water, and WRD screening limits for freshwater bathing. Based on the results of this study, it was believed by the authors that surface waters within the area studied had been impacted by bacteria and trace metals, and that such impacts were primarily due to municipal and residential development, other wastewater discharges, recreational uses, farming and livestock grazing, and abandoned and active coal mines. However, given the fact that the assessment was done using some very old monitoring data (i.e., back to 1946 in some cases), it is likely that some of the problems identified have since been rectified (e.g., those related to municipal discharges), and that other problems related to coal mining have diminished somewhat due to the fact that there are far fewer active mines now than there were during the time period studied.

Many of the contaminant exceedances described above are probably not particularly important today either because of very low exceedance percentages (e.g., 5% of the total observations or less), or because such exceedances occurred over 20 years ago. Based on the above limitations, it appears that the primary pollutants of concern now (particularly in the part of the Gauley River that flows through the park, as well as Summersville Lake/Reservoir, and the Meadow River that flows into the park from the south) are dissolved oxygen, pH, bacteria (total coliform and fecal coliform), cadmium, lead, mercury, and thallium. These concerns are borne out by the fact that many of the surface water bodies in and around the Gauley River NRA have been included on West Virginia's 303d list (as discussed in a later section) for impairments due to mine drainage and fecal coliform.

Specially Designated Surface Water Bodies

There are over 4700 miles of streams depicted in the watershed in Figure 1 that serves as the drainage area for the Gauley River NRA. Of this total, approximately 10% have been designated as "high quality" or similarly-designated stream (see Figure 4). Of the approximately 45.9 miles of streams contained with the park boundary, about 32.2 stream miles have been designated as being "high quality", including the Gauley River, Collison Creek, Dogwood Creek, Meadow River, Laurel Creek (2 separate streams), Horseshoe Creek, and Peter's Creek (see Figure 5). Table 2 provides information on the status of all streams falling within the park boundary in terms of meeting their designated uses, and Table 3 provides descriptions of each of these uses.

Figure 4. Location of specially designated streams.

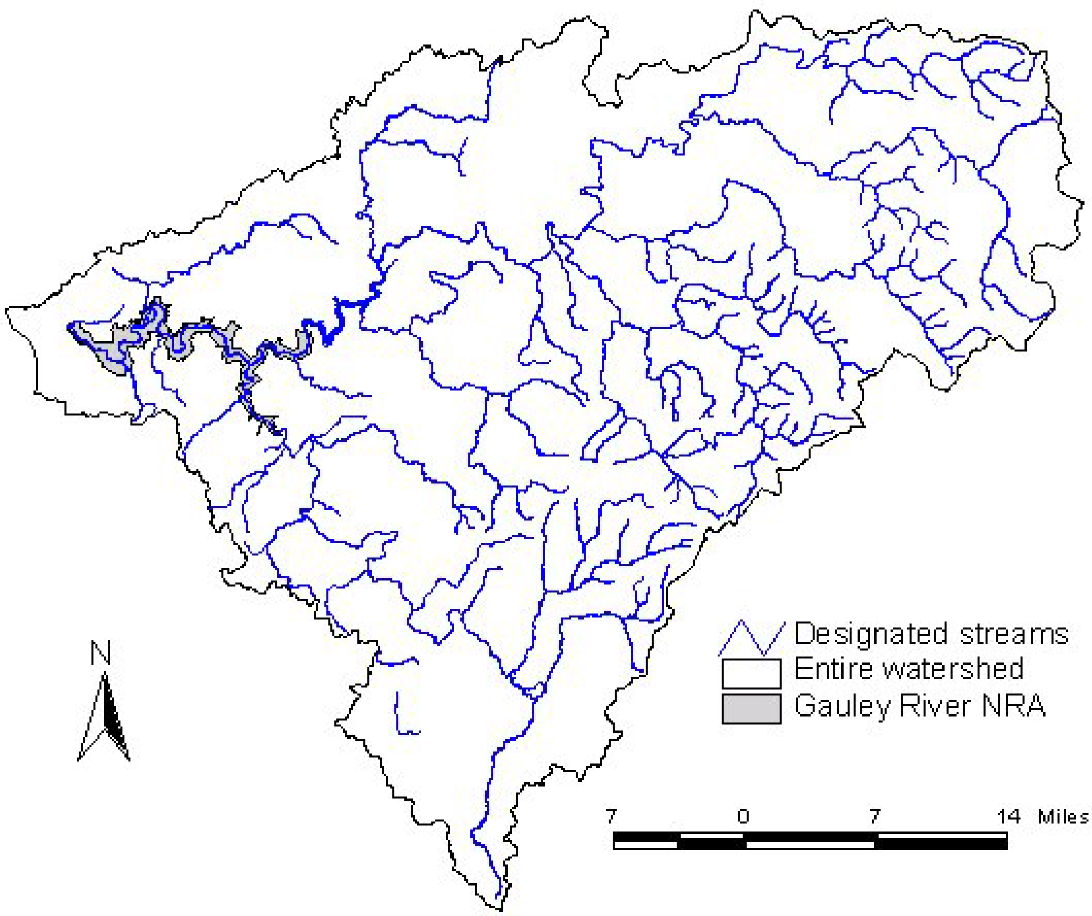


Table 2. Status of designated uses of streams within the park boundary.

Stream	Stream Miles or Lake Size	Category	Agricultural and Wildlife Uses	Public Water Supply	Trout Waters	Warm Water Fishery Streams	Water Contact Recreation	High Quality
Gauley River	24.60	5	Fully Supporting	Fully Supporting	N/A	Not Supporting	Fully Supporting	Yes
Sugar Creek	0.64	2	Fully Supporting	Insufficient Information	N/A	Insufficient Information	Insufficient Information	No
Horseshoe Creek	0.83	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	Yes
Beech Run	1.12	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Peters Creek	5.60	5	Fully Supporting	Not Supporting	Not Supporting	N/A	Not Supporting	Yes
Bucklick Branch	0.35	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Laurel Creek	0.17	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	Yes
UNT/Gauley River	0.66	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
UNT/Gauley River	0.56	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Ramsey Branch	0.56	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Meadow Creek	1.04	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Staton Branch	0.35	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Meadow River	1.60	5	Fully Supporting	Not Supporting	N/A	Fully Supporting	Not Supporting	Yes
Surbaugh River	0.29	3	Not Assessed	Not Assessed	Not Assessed	N/A	Not Assessed	No
Dogwood Creek	0.44	3	Not Assessed	Not Assessed	Not Assessed	N/A	Not Assessed	Yes
Hedricks Creek	0.32	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Arrowwood Creek	0.33	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Collison Creek	0.17	3	Not Assessed	Not Assessed	Not Assessed	N/A	Not Assessed	Yes
Laurel Creek	0.78	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	Yes
Big Run	0.51	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No

Table 3. Various “use-related” descriptions for streams used in West Virginia.

West Virginia 305b Category Descriptions

Category 1: Fully Supporting all designated uses.
Category 2: Fully supporting some designated uses, but no or insufficient information exists to assess the other designated uses.
Category 3: Insufficient or no information exists to determine if any of the uses are being met.
Category 4a: Waters that already have an approved TMDL but are still not meeting standards.
Category 5: Waters that have been assessed as impaired and are expected to need a TMDL.

West Virginia Use Attainment Descriptions

Fully Supporting: The sampled data suggest that stream can attain the designated use.
Insufficient Information: Some data suggest that stream may or may not attain the designated use. Not enough samples to conclude whether or not the stream can attain the designated use.
Not Supporting: The sample data suggest that stream cannot attain the designated use.
Not Assessed: No data have been collected.
N/A: No assessment information provided.

West Virginia Special Waters Designated Use Descriptions

Public Water Supply: This category is used to describe waters which, after conventional treatment, are used for human consumption. This category includes streams on which the following are located:

a) All community domestic water supply systems;
b) All non-community domestic water supply systems (i.e., hospitals, schools, etc.);
c) All private domestic water systems;
d) All other surface water intakes where the water is used for human consumption. The manganese human health criteria shall not apply where the discharge point of the manganese is located more than five miles upstream from a known drinking water source.

Agricultural and Wildlife Uses:

a) Irrigation – This category includes all stream segments used for irrigation.
b) Livestock watering – This category includes all stream segments used for livestock watering.
c) Wildlife – This category includes all stream segments and wetlands used by wildlife.

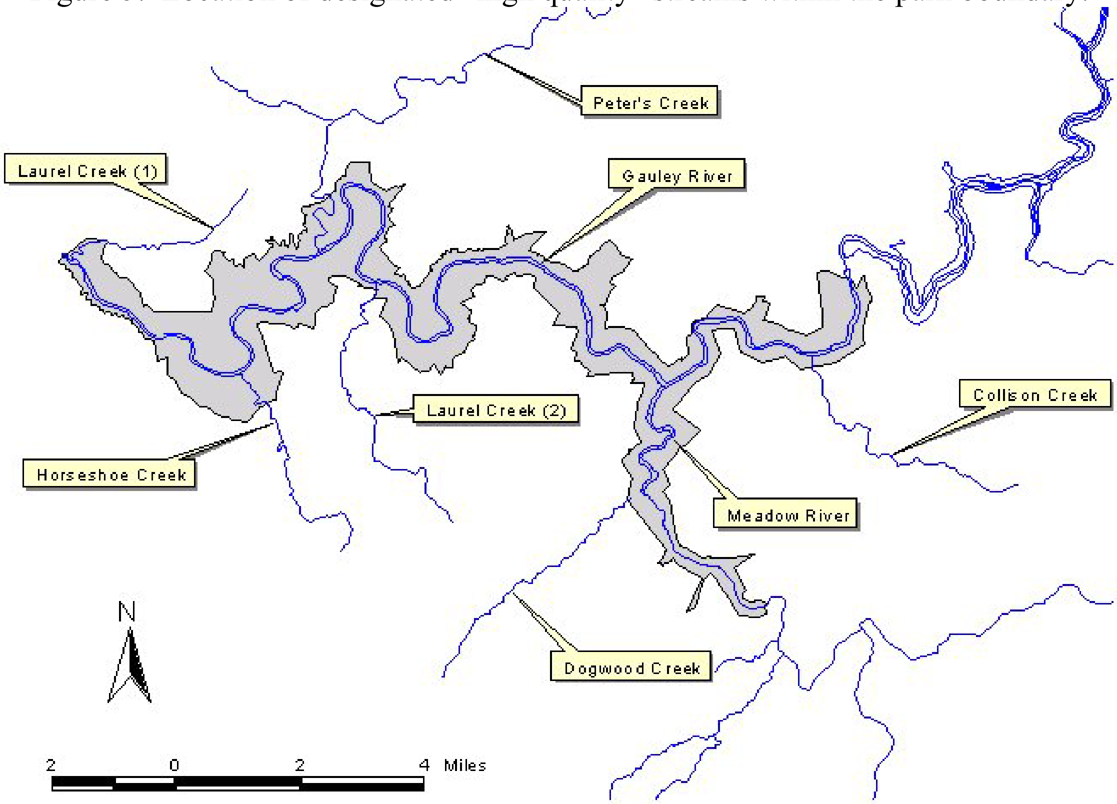
Water Contact Recreation: This category includes swimming, fishing, water skiing and certain types of pleasure boating such as sailing in very small craft and outboard motor boats.

Warm Water Fishery Streams: Streams or stream segments which contain populations composed of all warm water aquatic life.

Trout Waters: Streams or stream segments which sustain year-round trout populations. Excluded are those streams or stream segments which receive annual stockings of trout but which do not support year-round trout populations.

High Quality Waters: Waters whose quality is equal to or better than the minimum levels necessary to achieve the national water quality goal uses.

Figure 5. Location of designated “high quality” streams within the park boundary.



As defined by the State of West Virginia, "high quality waters" are those waters whose quality is equal to or better than the minimum levels necessary to achieve the national water quality goal uses. Such waters require what is defined as “Tier 2” protection, which requires that the existing high quality waters of the state must be maintained at their existing high quality unless it is determined after satisfaction of the intergovernmental coordination of the state’s continuing planning process and opportunity for public comment and hearing that allowing lower water quality is necessary to accommodate important economic or social development in the area in which the waters are located. If limited degradation is allowed, it shall not result in injury or interference with existing stream water uses or in violation of state or federal water quality criteria that describe the base levels necessary to sustain the national water quality goal uses of protection and propagation of fish, shellfish and wildlife and recreating in and on the water.

High quality waters may include but are not limited to the following:

- Streams designated by the West Virginia Legislature under the West Virginia Natural Stream Preservation Act, pursuant to W. Va. Code §22-13-5;
- Streams listed in West Virginia High Quality Streams, Fifth Edition, prepared by the Wildlife Resources Division, Department of Natural Resources (1986); and
- Streams or stream segments which receive annual stockings of trout but which do not support year-round trout populations.

Current Listing of Water Quality Impairments

As shown in Figure 6, a number of surface water bodies within the drainage area of the Gauley River NRA (including Summersville Lake/Reservoir) have been identified as being impaired on West Virginia's 303d list. As can be seen from Figure 4, many of the impaired streams have also been designated as "special" or worthy of protection based on one or more criteria. Most of the impaired surface waters in the larger watershed are listed for problems related to dissolved aluminum, iron, and/or fecal coliform. Table 4 provides information on the impaired surface water bodies either in or immediately adjacent to the Gauley River NRA, and Figure 7 depicts the location of these streams. In the cases where the "causes" have been listed as "unknown", it is very likely that the problems are due to mine drainage (in the case of metals) and untreated wastewater in the case of fecal coliform. Out of approximately 45.9 miles of streams located within the park, about 69% (31.8 miles) have been designated as being water quality-impaired. It should be noted that Peter's Creek was listed for a "total aluminum" impairment in the past, but has since been "de-listed" for this particular cause due to a recent change in the assessment criteria for this particular pollutant by the West Virginia DEP.

According to the Horizon report, there are two industrial dischargers located within the park boundary (permit numbers WV0043915 and WV0046779). Both of these facilities appear to be "mine-related", and are located at the lower end of the park. Although these sites may contribute somewhat to "mine-related" impairments to the Gauley River, it is more likely that such impairments are caused by much larger mine operations, both active and inactive, in the headwaters of the Gauley River and in the Peter's Creek sub-watershed.

Figure 6. Location of impaired surface water bodies on 303d list.

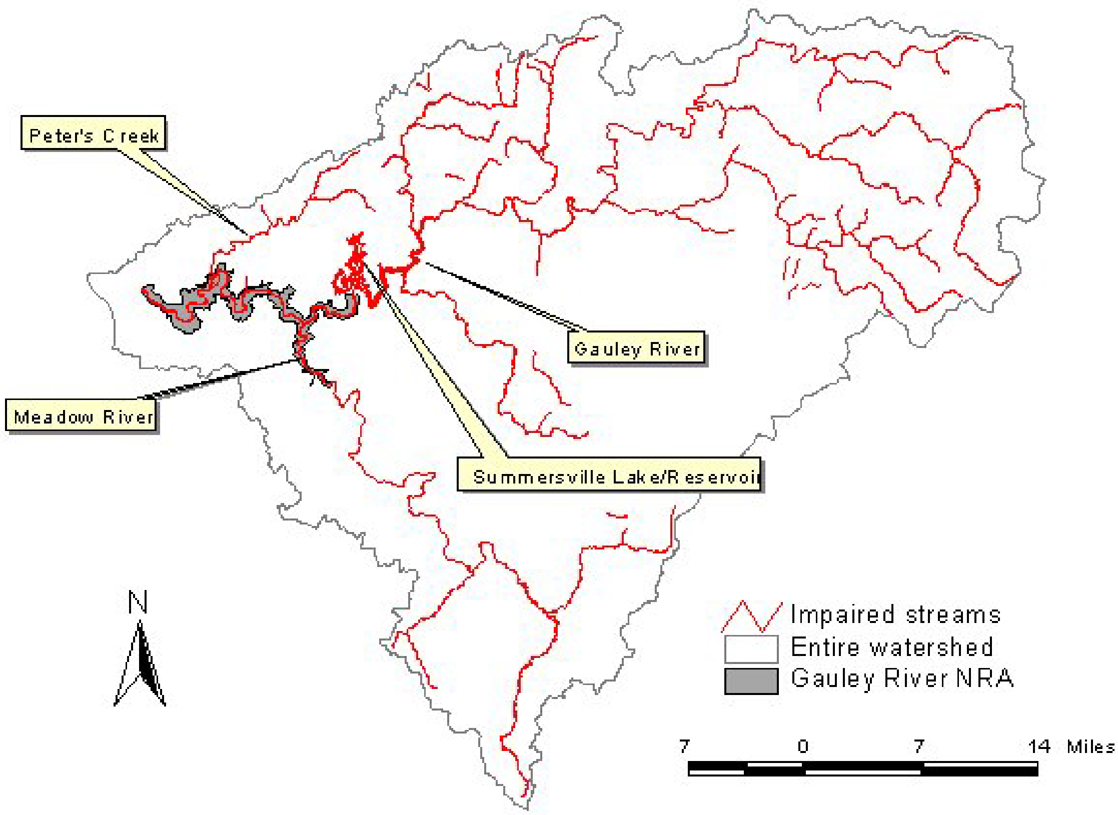


Table 4. Sources and causes of listed impairments.

Surface Water Body	Cause	Source	On 2002 List?
Gauley River	Dissolved aluminum	Unknown	No
Meadow River	Fecal coliform	Unknown	No
Summerville Lake	Mercury	Unknown	Yes
Peter's Creek	Fecal coliform	Unknown	Yes
Peter's Creek	Iron and Manganese	Mine drainage	Yes

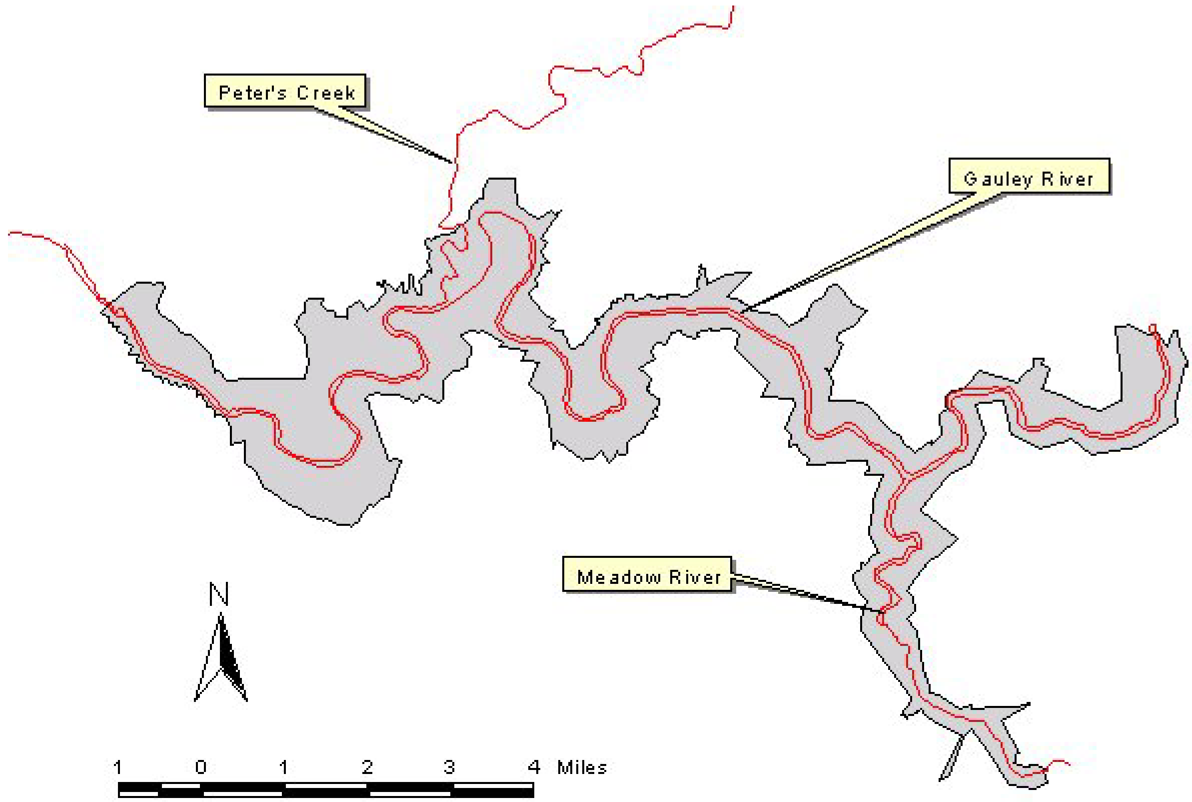


Figure 7. Location of impaired streams within the park boundary.

Current Water Quality Trends and Loading Rates

Using more recently-compiled water quality data, mean annual concentration values for selected parameters were compared with criteria similar to those used in the earlier Horizon reports to assess whether potential water quality problems identified in the past still exist. These selected parameters were based on various factors, including past problems described in the Horizon report, problems identified in the 303d listings, and the list of core parameters to be used as "vital sign" indicators as identified by WRD. Temperature is also listed as one of the core parameters, but was not included here for several reasons. First, there are no established temperature criteria to use to evaluate the condition of the aquatic system. Secondly, trends in temperature could be evaluated but the results may prove misleading due to natural long-term air temperature trends and the relationship between air and water temperature (i.e. gradual warming of mean annual water temperature may reflect recent warming of the climate, and not watershed disturbance).

Temporal trends for selected water quality parameters were also determined to provide a sense of potential changes in such parameters over time (i.e., are problems getting worse or better?). Temporal trends were evaluated for each constituent that exceeded concentration criteria during the period of analysis (1990-present). To determine the existence of a temporal trend, concentration values were plotted against date and fit with a linear trendline in MS Excel. Additionally, loading rates for various water quality parameters were estimated for the entire park drainage area and another sub-area to provide another measure of potential water quality problems.

Based upon information provided in previous sections, water quality statistics and trends were determined for total nitrogen, total phosphorus, specific conductivity, pH, fecal coliform, mercury, iron, aluminum, manganese, and dissolved oxygen where the appropriate data were available (see Table 5). In all cases, an attempt was made to use any sample data collected from 1990 up to the present. However, as can be seen from Table 5, data from some of these sites (particularly the "GARI" sites) were only as recent as 1995. These parameters were selected because they are commonly used to assess certain aspects of the hydrologic system, and are briefly discussed below. The water quality stations for which data were compiled for this analysis are shown in Figure 8.

Specific Conductivity is the ability of a substance to conduct an electrical current across a given length at a specified temperature. Specific Conductivity can be used as an indicator of water quality because pure water has a very low electrical conductance. As concentrations of different ions dissolved in water increase, so does the conductivity. Therefore, conductivity is directly related to the amount of charged particles (i.e. heavy metals, clay particles, etc.) contained within a water sample. While there are no set conductivity criteria for fresh water, specific conductance is linearly related to the concentration of total dissolved solids in a sample. For the purposes of this investigation,

$$0.65*K = S$$

where K is conductance (micromhos) and S is dissolved solids (mg/L). The EPA has a recommended criterion of 500 mg/L for dissolved solids in drinking water (US EPA, 2002a). This corresponds to a specific conductivity of 325 micromhos, given the equation above.

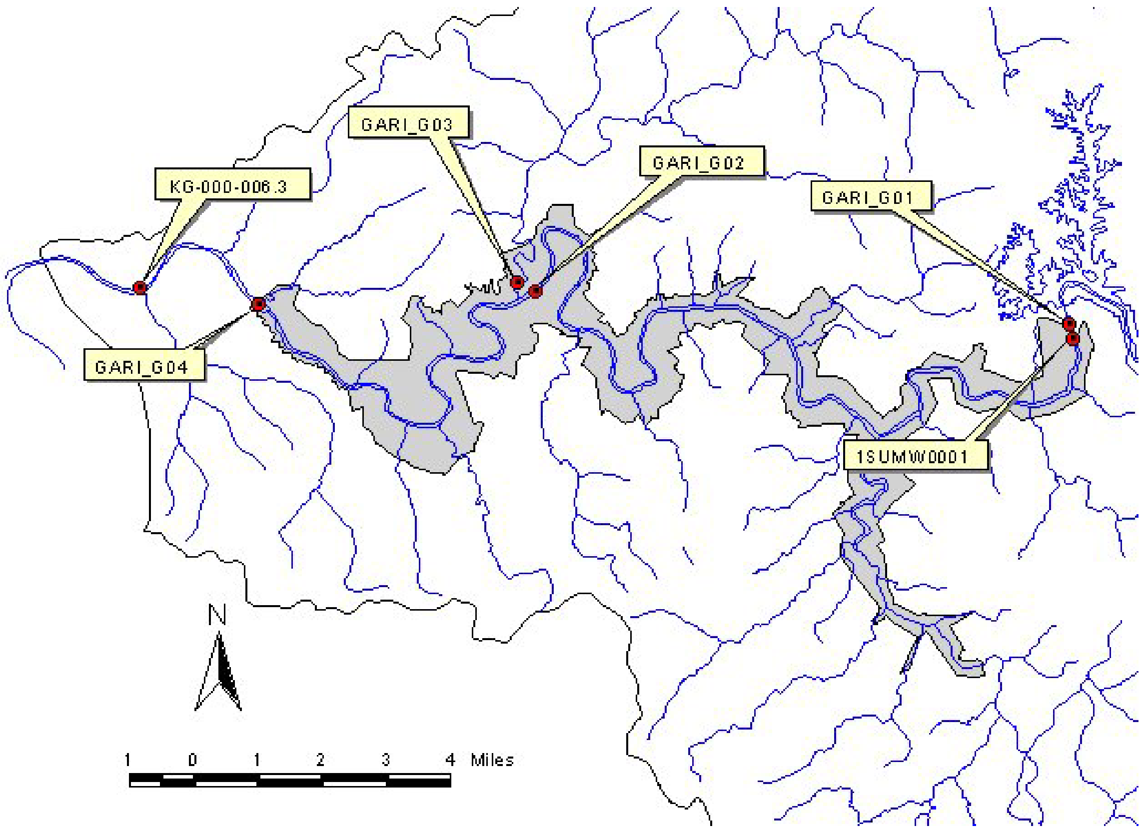
pH is one of the most general indicators of water quality. The natural logarithm of hydrogen ion concentration in solution, pH ranges from 0-14 with 7 being neutral. pH values ranging from approximately 6-8 naturally occur in freshwater aquatic systems. The EPA-established criterion

Table 5. Results of analyses based on recently-compiled water quality data at stations in and around Gauley River NRA.

Chemical Characteristic	Station ID	Station Name	Exceedances	No. Obs.	% Exceed	Begin Date	End Date	Min. Value	Max. Value	Avg. Value	Trend
MANGANESE, TOTAL (UG/L AS MN)	1SUMW0001	GAULEY RIVER	15	23	65%	Aug-93	Aug-98	51	161	78.27	NA
PH, LAB, STANDARD UNITS	GARI_G01	SUMMERSVILLE DAM	5	61	8%	May-91	Jun-95	5.4	6.4	6.06	+
FECAL COLIFORM,MEMBR FILTER	GARI_G02	MID GAULEY	1	56	2%	May-91	Jun-95	275	275	275.00	+
PH, LAB, STANDARD UNITS	GARI_G02	MID GAULEY	2	61	3%	May-91	Jun-95	6	6.3	6.15	+
FECAL COLIFORM,MEMBR FILTER	GARI_G03	PETERS CREEK	17	57	30%	May-91	Jun-95	207	10666.7	1391.76	-
IRON, TOTAL (UG/L AS FE)	GARI_G03	PETERS CREEK	2	10	20%	May-92	Apr-95	1931	18138	10034.50	NA
SPECIFIC CONDUCTANCE	GARI_G03	PETERS CREEK	30	59	51%	Jun-91	Jun-95	330	535	412.37	-
FECAL COLIFORM,MEMBR FILTER	GARI_G04	SOUTH SIDE SWISS	2	55	4%	May-91	Jun-95	244	261	252.50	NA
PH, LAB, STANDARD UNITS	GARI_G04	SOUTH SIDE SWISS	3	60	5%	May-91	Jun-95	6.3	9.2	7.30	+
FECAL COLIFORM,MEMBR FILTER	KG-000-006.3	Gauley River at Beech Glen	6	19	32%	Jan-99	Oct-03	240	740	409.33	+
MANGANESE, TOTAL (UG/L AS MN)	KG-000-006.3	Gauley River at Beech Glen	4	20	20%	Jan-99	Oct-03	60	154	100.35	+
Phosphorus as P	KG-000-006.3	Gauley River at Beech Glen	2	17	12%	Jan-99	Oct-03	0.14	0.28	0.21	NA
IRON, TOTAL (UG/L AS FE)	KG-000-006.3	Gauley River at Beech Glen	1	20	5%	Jan-99	Oct-03	1190	1190	1190.00	NA
ALUMINUM, TOTAL (UG/L AS AL)	550441	Gauley River at Beech Glen	8	62	13%	Jan-90	Jun-95	760	11258	2910.50	NA
FECAL COLIFORM,MEMBR FILTER	550441	Gauley River at Beech Glen	4	60	7%	Jan-90	Jun-95	230	900	445.00	+
IRON, TOTAL (UG/L AS FE)	550441	Gauley River at Beech Glen	1	61	2%	Jan-90	Jun-95	1300	1300	1300.00	NA
MANGANESE, TOTAL (UG/L AS MN)	550441	Gauley River at Beech Glen	9	62	15%	Jan-90	Jun-95	55	100	68.00	+
PH (STANDARD UNITS)	550441	Gauley River at Beech Glen	2	63	3%	Jan-90	Jun-95	4.2	6.2	5.20	NA
PH, LAB, STANDARD UNITS	550441	Gauley River at Beech Glen	1	15	7%	Jan-90	Mar-91	6.2	6.2	6.20	NA
FECAL COLIFORM,MEMBR FILTER	WA96-K05	Gauley River at Beech Glen	4	12	33%	Mar-96	Oct-98	320	600	410.00	+
IRON, TOTAL (UG/L AS FE)	WA96-K05	Gauley River at Beech Glen	1	12	8%	Mar-96	Oct-98	2400	2400	2400.00	NA
MANGANESE, TOTAL (UG/L AS MN)	WA96-K05	Gauley River at Beech Glen	1	12	8%	Mar-96	Oct-98	95	95	95.00	+

Notes: 1) Station IDs KG-000-006.3, 550441, and WA96-K05 represent the same station location; the ID codes were changed only to reflect the different dates at which samples were taken.
2) "Exceedances" refers to the number of times observed values exceeded the threshold criteria used for any given parameter.
3) For "Trend", a "+" indicates an upward trend in observed concentrations or counts, and "-" indicates a downward trend, and "NA" indicates no obvious trend

Figure 8. Location of water quality monitoring stations used for current analysis.



for aquatic life protection includes pH values between 6.5 and 9.0. For the purposes of this investigation, recorded values outside of this range were flagged as an indication of impairment.

Fecal Coliform bacteria levels were used as an indicator of failing sewage treatment facilities or otherwise untreated wastewater upstream of a sampling point. In discussion of indicator bacteria, it should be noted that the EPA recommends the analysis of either E. Coli or enterococci bacteria for this purpose. However, there are very few samples of E. Coli and enterococci bacteria available for assessment of aquatic ecosystem health. Therefore, Fecal Coliform data were examined using an EPA (2002b) established threshold of 200 colony forming units (CFU).

High loads and or concentrations of *Total Nitrogen, Total Phosphorus, and Total Suspended Sediment* are often correlated with excessive fertilization of agricultural land, ineffective agricultural management strategies, high levels of impervious surface area, and other anthropogenic disturbances within the watershed. No nationally recognized criteria exist for these three parameters, so criteria published by Sheeder and Evans (2004) were employed. The criteria were developed for the state of Pennsylvania, and are though to be relatively accurate for regions of New York and West Virginia as well. The criteria for total nitrogen, total phosphorus, and total suspended sediment are 2.01 mg/L, 0.07 mg/L, and 197.27 mg/L respectively.

Elevated concentrations of *Mercury, Iron, Aluminum, and Manganese* and many other metals are commonly associated with large-scale disturbances within a watershed including mining and large-scale construction projects. Elevated metals concentrations can also result from acidic deposition, low watershed acid buffering capacity, and other factors. These four metals were selected from the larger suite of metals associated with mining/disturbance impairments because each has been explicitly implicated as the cause of impairment in section 303d-listed watersheds in Pennsylvania, West Virginia, New York and/or New Jersey. The EPA has published criterion for each of the metals analyzed in this report (USEPA, 2002c). Mercury is designated as a priority pollutant, and has a freshwater CMC criterion of 1.4 ug/l. Iron, Aluminum and Manganese are listed as non-priority pollutants. Iron and Aluminum are assigned freshwater criteria of 1000 ug/L (CCC) and 750 ug/L (CMC), respectively. There is no freshwater criterion set for Manganese. In the absence of an aquatic health criterion, the EPA human health consumption criterion of 50 ug/L was used to define exceedances.

Dissolved Oxygen concentration is the final parameter selected for analysis in this report. Dissolved oxygen concentrations above designated thresholds are essential for the survival of aquatic vertebrates and invertebrates, while low values suggest nuisance algae populations stemming from nutrient pollution. Several different criteria have been specified, due to the varying tolerances of adult and juvenile, warm water and cold water species. For the purposes of this investigation, the one-day minimum, coldwater fishery criterion of 4 mg/L (USEPA, 1986) is employed. This criterion is thought to be the most appropriate because the limit will include all warm water violations, without including samples that would be flagged using the coldwater, juvenile fish criteria (juvenile fish are prevalent during the spring, when mechanical saturation provides sufficient oxygen levels in all but the most impaired watersheds. These watersheds will be identified using the one-day minimum coldwater fishery criteria or via one of the other chemicals).

From the results in Table 5, it can be seen that pH (probably due to mine drainage from the upper reaches of the Gauley River) is still an issue in the Summersville Lake/Reservoir. Although the number of criterion exceedances are less than 10%, there was an upward trend in observed pH values from 1991 to 1995. This supposition is corroborated by the high manganese levels observed at station 1SUMW0001 on the Gauley River below the Summersville Dam. The Mid Gauley station did not record many extreme pH and fecal coliform values, but an upward trend in both was noted during the period sampled (1991-1995). In the Peter's Creek sub-watershed, values for iron and specific conductance (probably related to mine drainage) appeared to level off or decline slightly from 1991 to 1995, but the number of criterion exceedances were still relatively high. Problems with fecal coliform seem to be apparent in this sub-watershed as well. As indicated by the two monitoring stations located at the lower end of the Gauley River (GARI_G04 and the monitoring station near Beech Glen), problems still exist with high fecal coliform values (which are most likely related to untreated wastewater originating from other portions of the watershed such as Meadow River) and constituents most likely associated with mine drainage (e.g., pH, aluminum, and iron). Fecal coliform and manganese values, in particular, are still relatively high, and seem to be increasing through time.

In addition to the water quality trend analyses described above, mean annual loading rates for selected pollutants in the watershed were also done. More specifically, loading rates were estimated for the entire watershed and one of the sub-watersheds identified earlier in Figure 3 as "Sub-area 2". It was not possible to calculate loading rates for Sub-area 1 since there was no water quality monitoring station located near the USGS flow gage (3190400) that defines this watershed.

In this case, loading rates were estimated for total nitrogen and total phosphorus for both areas, and total suspended solids (TSS; essentially, total suspended sediment) only for Sub-area 2 since TSS data were not available for the water quality monitoring station at the outlet for the entire watershed (see Table 6). These estimates were subsequently compared with "threshold" loading rates developed by Sheeder and Evans (2004) for evaluating watersheds in Pennsylvania. These threshold values (also shown in Table 6) reflect values above which watersheds are believed to show signs of water quality impairment. Based on these particular criteria, it appears that nutrient and sediment loads do not represent a significant water quality problem in the Gauley River watershed. By extension, these results suggest that agricultural sources (i.e., via soil erosion and nutrient applications) are probably not important sources of pollution in the park or surrounding areas.

Table 6. Estimated and threshold loading rates (in kg/ha per year).

Area	USGS Gage	WQ Station	TSS	TN	TP
Entire watershed	3192000	550441	-	4.6	0.13
Sub-area 2	3189600	1SUMW0001	391.1	4.0	0.16
Threshold value	-	-	785.3	8.6	0.30

TMDL Development

The West Virginia Department of Environment Protection (DEP) is planning to conduct total maximum daily load (TMDL) assessments for the impaired waters in and around the park discussed in previous sections. A TMDL is essentially a plan of action used to clean up streams that are not meeting water quality standards. The plan includes pollution source identification and strategy development for contaminant source reduction or elimination. As of the date of this document (September 2004), no TMDLs have been developed for any of the "303d-listed" waters within the Gauley River watershed, including those within the Gauley River NRA. Currently, the West Virginia DEP has plans to develop TMDLs for all of these impaired waters (with some exceptions) by the end of 2006. The three exceptions are the Gauley River itself, the Meadow River, and the Summersville Lake/Reservoir. The TMDLs for these three impaired waters are not scheduled to be completed until 2016.

Presence of Existing Gages and Monitoring Sites

At present, there are four active USGS stream flow gages in and around the Gauley River NRA (see Figure 1). Data from two of these gages (03189600 and 03192000) were used in the loading rate calculations described in the previous section. Descriptive information pertaining to all four gages is presented in Table 7. With respect to water quality monitoring stations, there appears to be only 1 active, long-term station located in or near the park. This station (KG-000-006.3) is maintained by the West Virginia DEP (Div. of Water and Waste Management), and is situated on the Gauley River near Beech Glen, and is about a mile upstream from USGS gage 3192000 as depicted in Figure 3. Based on a review of recently recorded STORET data, this station appears to monitor for a fairly complete suite of trace metals, algae, nutrients, acidity, pH, temperature, dissolved oxygen, specific conductance, and more recently, total suspended solids and fecal coliform.

Table 7. Active USGS stream gages.

Site No.	Location
3189100	GAULEY RIVER NEAR CRAIGSVILLE, WV
3189600	GAULEY RIVER BELOW SUMMERSVILLE, WV
3190400	MEADOW RIVER NEAR MT. LOOKOUT, WV
3192000	GAULEY RIVER ABOVE BELVA, WV

In addition to the long-term station described above, the West Virginia DEP has also established a number of shorter-term stations that will be used to gather “pre-TMDL” data to be used in support of various TMDL development efforts in the Gauley River watershed. One of these stations is located near the site of the discontinued “GARI_G03” station depicted earlier in Figure 8.

Recommendations for Future Monitoring

Based on the analyses presented above, it appears that problems related to mine drainage are still prevalent in waters flowing into and through the Gauley River NRA (particularly in the Peter’s Creek area to the north of the park and the Beaver Creek and Brushy Fork areas to the northeast and east of the park). As a result of mining activities in these areas, Summersville Lake/Reservoir has experienced elevated pH and trace metal concentrations in the past, and continues to do so at present.

In the past, several water quality monitoring stations were used to monitor mine drainage problems in these areas (see stations GARI_G01, GARI_G02, GARI_G03, and 1SUMW0001 in Figure 8), but these stations have since been discontinued. These or similar stations need to be re-established in order to properly assess such problems in preparation for TMDL assessments completed for the Gauley River and Summersville Lake in the future. As discussed in a previous section, the West Virginia DEP is planning to complete all required TMDLs for 303-listed waters in the Gauley River watershed (with the exception of the Gauley River, Meadow River, and Summersville Lake) by the end of 2006. In anticipation of this, the DEP has already established a short-term station near the older "GARI_G03" site that could be used to support any analyses done for Peter's Creek. This station is currently being used by DEP to monitor for a suite of AMD-related contaminants as well as for fecal coliform.

As described earlier, the West Virginia DEP is not planning to complete TMDL assessments for the Gauley and Meadow Rivers until 2016. It is likely that the DEP will conduct "pre-TMDL" stream sampling in these streams as it is currently doing for Peter's Creek. However, it is not known when this will occur. In the meantime, it might be worth considering the re-establishment of water quality monitoring sites near USGS gages 3189600 and 3190400 shown in Figure 3 in anticipation of future TMDL assessments done for the Gauley River and Meadow River, respectively. For the Gauley River, focus should be placed on monitoring contaminants related to mine drainage (e.g., Fe, Al, Mn, and pH). For the Meadow River, emphasis should be placed on monitoring pH levels.

Literature Cited

National Park Service. 1995. Baseline Water Quality Data Inventory and Analysis: Gauley River National Recreation Area, Tech. Report NPS/NRWRD/NRTR-95-74, 603 pp.

Sheeder, S. A. and B.M. Evans, 2004. Estimating Nutrient and Sediment Threshold Criteria for Biological Impairment in Pennsylvania Watersheds. Journal of the American Water Resources Association (JAWRA) 40(4): 881-888.

USEPA (U.S. Environmental Protection Agency), 2002a. List of Drinking Water Contaminants & MCLs. EPA 816-F-02-013, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2002b. Implementation Guidance for Ambient Water Quality Criteria for Bacteria. EPA-823-B-02-003, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2002c. National Recommended Water Quality Criteria: 2002. EPA-822-R-02-047, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 1986. Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003, U.S. Environmental Protection Agency, Washington, D.C.

WATER QUALITY SUMMARY

for

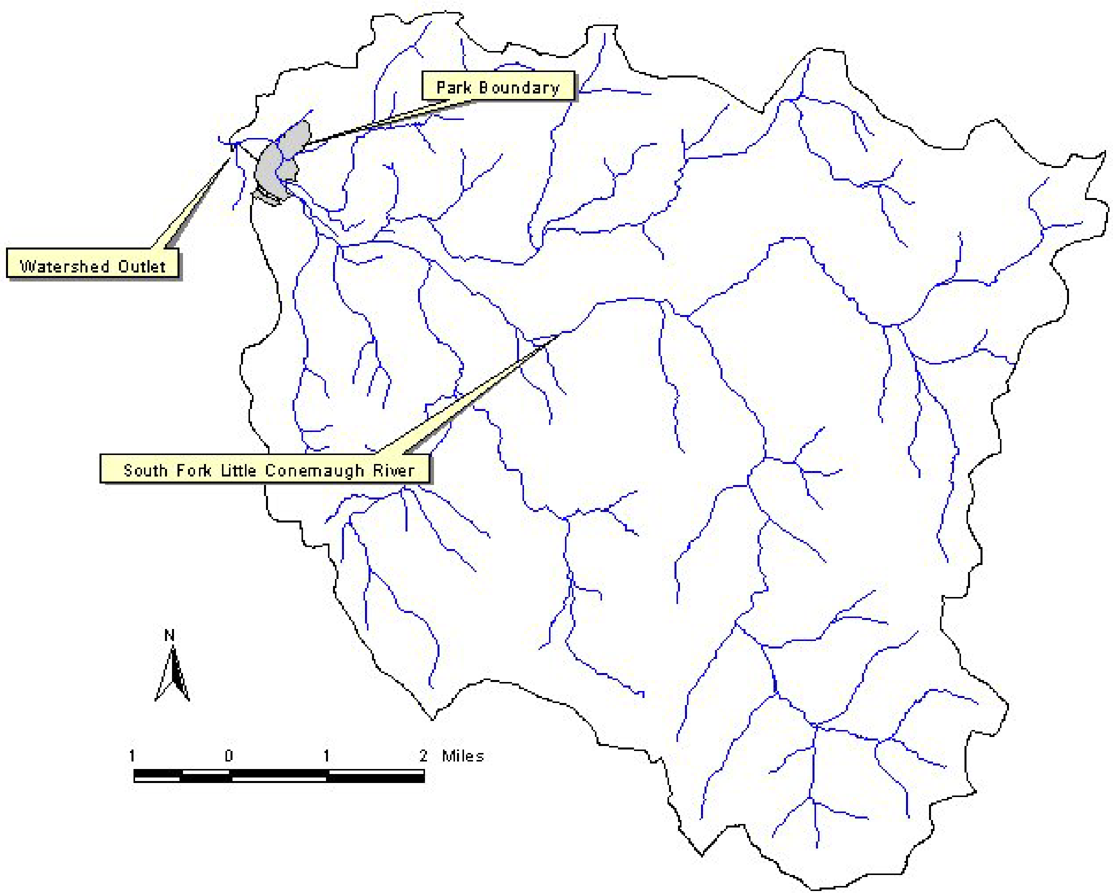
JOHNSTOWN FLOOD NATIONAL MEMORIAL

September 2004

Overview of Park/Watershed Characteristics

The Johnstown Flood National Memorial (JOFL) is located northeast of Johnstown, PA, and is approximately 172 acres in size. For the purposes of this assessment, the watershed for JOFL is defined by the drainage area of the streams that run through or drain this particular site. This watershed is about 53 square miles in size, contains about 102 miles of streams, and is comprised primarily of woodland. There are also substantial areas of abandoned mine land to the south and east of the park, as well as pockets of urban land to the east and south, and agricultural land to the north and south. The park itself is primarily wooded with pockets of open and developed land. There are no USGS gages located near the site. Hence, an estimate of stream flow in the South Fork of the Little Conemaugh River that runs through the park cannot be provided.

Figure 1. Location of park and watershed outlet.



Historical Water Quality Overview

Detailed analyses of water quality within and around JOFL, as well as other national parks, have previously been prepared by the Water Resources Division (WRD) of the National Park Service (NPS, 1995). These reports are typically referred to as "Horizon" reports after the contractor that performed most of the analyses (Horizon Systems Corporation). In the case of the JOFL, the Horizon report included an analysis of this park as well as one for the Allegheny

Portage Railroad National Historic Site. For these two areas, the analyses described in the Horizon report were collectively done for the period 1926-1997 using data for a total of 381 water quality monitoring stations (both active and inactive) in and around the two parks. It should be noted here, however, that almost all of the stations reported on are located on streams that do not flow through the parks or do not contribute any flow or loads to either park area. Therefore, most of the results presented in the earlier report (and summarized below) may not be relevant with respect to contemporary water quality issues facing JOFL.

In the Horizon report, it was noted that during the 1926-1997 period, stream observations for a total of 17 parameters exceeded the screening criteria used in the study at least once within the combined study area boundary used (which as noted above, was larger than the drainage area for the park). These parameters included dissolved oxygen, pH, turbidity, bacteria (total coliform and fecal coliform), total alkalinity, cyanide, sulfate, nitrate, antimony, beryllium, cadmium, copper, lead, nickel, thallium, and zinc. The criteria used for various parameters included EPA criteria for the protection of freshwater aquatic life and drinking water, and Water Resources Division (WRD) screening limits for freshwater bathing. Based on the results of this study, it was believed by the authors that surface waters within the area studied had been impacted by human activities, and that such impacts were primarily due to mining and quarrying activities, municipal and industrial wastewater discharges, agricultural operations, oil and gas development, stormwater runoff, recreational use, and atmospheric deposition. However, given the fact that the assessment was done using some very old monitoring data (i.e., back to 1926 in some cases), it is likely that some of the problems identified have since been rectified (e.g., those related to municipal and industrial discharges), and that other problems related to coal mining have diminished somewhat due to the fact that there are far fewer active mines now than there were during the time period studied.

Many of the contaminant exceedances described above are probably not particularly important today either because of very low exceedance percentages (e.g., 5% of the total observations or less), or because such exceedances occurred over 20 years ago. Based on the above limitations, it appears that the primary parameters of concern now in the areas surrounding JOFL are pH, cyanide, sulfate, copper, nickel, and zinc. These concerns are borne out by the fact that several of the streams in the larger watershed of which the park is a part (e.g., Otto Run, South Fork Little Conemaugh, and Sulphur Creek) have been included on Pennsylvania's 303d list (as discussed in a later section) for impairments due to abandoned mine drainage.

Specially Designated Surface Water Bodies

There are no specially-designated or otherwise protected streams (e.g., "high quality" streams) located within the park. However, all streams within the park (including the entire length of the South Fork Little Conemaugh River, and tributaries thereof) have been designated as "cold water fisheries". Table 1 provides descriptions of each of the various uses designated by the Commonwealth of Pennsylvania.

Table 1. Descriptions of designated water uses in Pennsylvania.

Protected Water Uses in Pennsylvania
CWF - *Cold Water Fishes* - Maintenance or propagation, or both, of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat
WWF - *Warm Water Fishes* - Maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat
MF - *Migratory Fishes* - Passage, maintenance and propagation of anadromous and catadromous fishes and other fishes which ascend to flowing waters to complete their life cycle.
TSF - *Trout Stocking* - Maintenance of stocked trout from February 15 to July 31 and maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
HQ - *High Quality Waters* - Surface waters having quality which exceeds levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water by satisfying § 93.4b(a). **EV** - *Exceptional Value Waters* - Surface waters of high quality which satisfy § 93.4b(b) (relating to antidegradation).

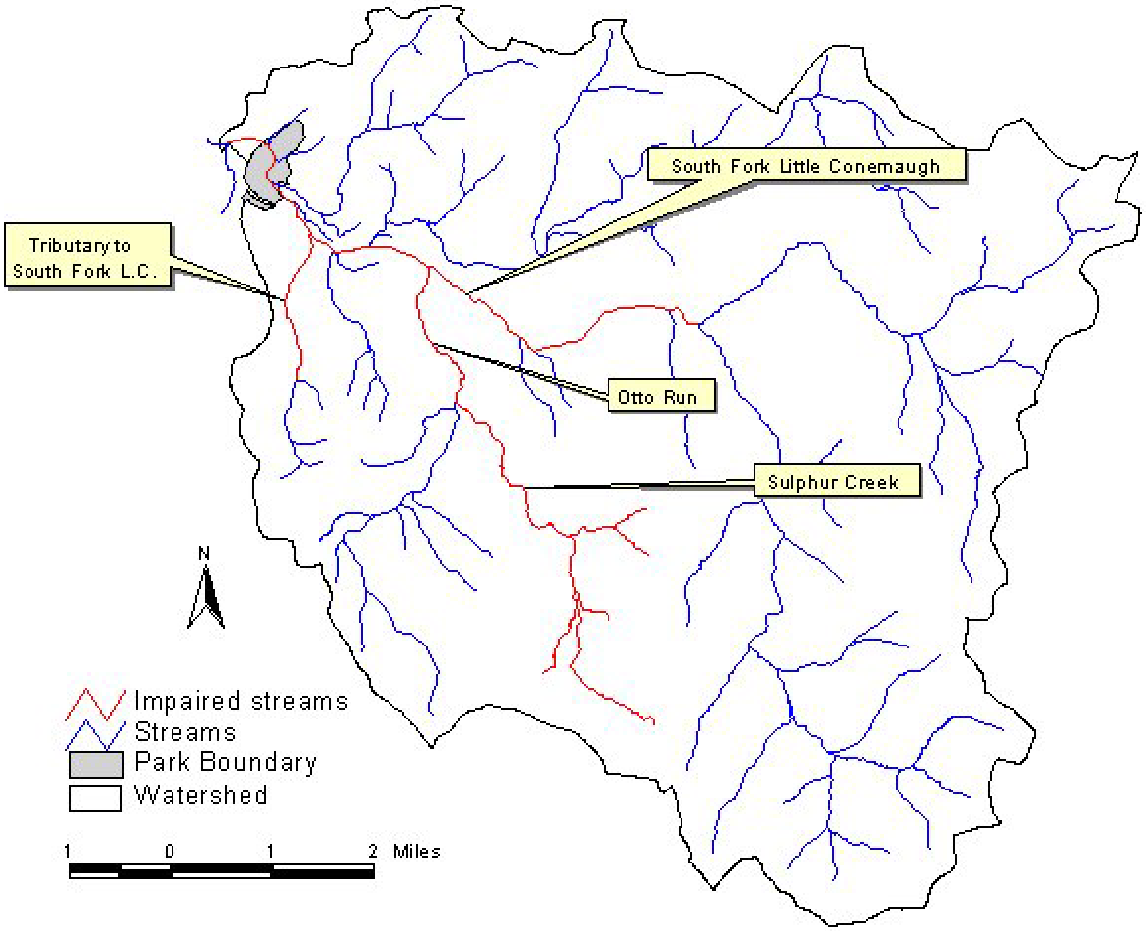
Current Listing of Water Quality Impairments

At present, the entire length of the South Fork Little Conemaugh contained within the park has been included on Pennsylvania's 303d list of impaired water bodies. In this case, the stream has been determined to be impaired by pH and metals originating from abandoned mine drainage. This stream reach was first listed in 2002. Figure 2 shows all of the 303d-listed impaired stream segments in the watershed in which the park is located, including the South Fork Little Conemaugh, Otto Run, Sulphur Creek, and tributaries thereof. All of these streams were determined to be impaired by metals and/pH from abandoned mine drainage.

Current Water Quality Trends

Using recently-compiled water quality data, mean annual concentration values for selected parameters were compared with criteria similar to those used in the earlier Horizon reports to assess whether potential water quality problems identified in the past still exist. These selected parameters were based on various factors, including past problems described in the Horizon report, problems identified in the 303d listings, and the list of core parameters to be used as "vital sign" indicators as identified by NPS WRD. Temperature is also listed as one of the core parameters, but was not included here for several reasons. First, there are no established temperature criteria to use to evaluate the condition of the aquatic system. Secondly, trends in temperature could be evaluated but the results may prove misleading due to natural long-term air temperature trends and the relationship between air and water temperature (i.e. gradual warming of mean annual water temperature may reflect recent warming of the climate, and not watershed disturbance).

Figure 2. Impaired stream reaches within the park and surrounding watershed.



Temporal trends for selected water quality parameters were also determined to provide a sense of potential changes in such parameters over time (i.e., are problems getting worse or better?). Temporal trends were evaluated for each constituent that exceeded concentration criteria during the period of analysis (1990-present). To determine the existence of a temporal trend, concentration values were plotted against date and fit with a linear trendline in MS Excel.

Based upon information provided in previous sections, water quality statistics and trends were determined for total nitrogen, total phosphorus, specific conductivity, pH, fecal coliform, cyanide, sulfate, copper, nickel, zinc, mercury, iron, aluminum, manganese, and dissolved oxygen where the appropriate data were available. These parameters were selected because they are commonly used to assess certain aspects of the hydrologic system, and are briefly discussed below. In all cases, an attempt was made to use any sample data collected from 1990 up to the present.

Specific Conductivity is the ability of a substance to conduct an electrical current across a given length at a specified temperature. Specific Conductivity can be used as an indicator of water quality because pure water has a very low electrical conductance. As concentrations of different ions dissolved in water increase, so does the conductivity. Therefore, conductivity is directly related to the amount of charged particles (i.e. heavy metals, clay particles, etc.) contained within a water sample. While there are no set conductivity criteria for fresh water, specific conductance is linearly related to the concentration of total dissolved solids in a sample. For the purposes of this investigation,

$$0.65*K = S$$

where K is conductance (micromhos) and S is dissolved solids (mg/L). The EPA has a recommended criterion of 500 mg/L for dissolved solids in drinking water (US EPA, 2002a). This corresponds to a specific conductivity of 325 micromhos, given the equation above.

pH is one of the most general indicators of water quality. The natural logarithm of hydrogen ion concentration in solution, pH ranges from 0-14 with 7 being neutral. pH values ranging from approximately 6-8 naturally occur in freshwater aquatic systems. The EPA-established criterion for aquatic life protection includes pH values between 6.5 and 9.0. For the purposes of this investigation, recorded values outside of this range were flagged as an indication of impairment.

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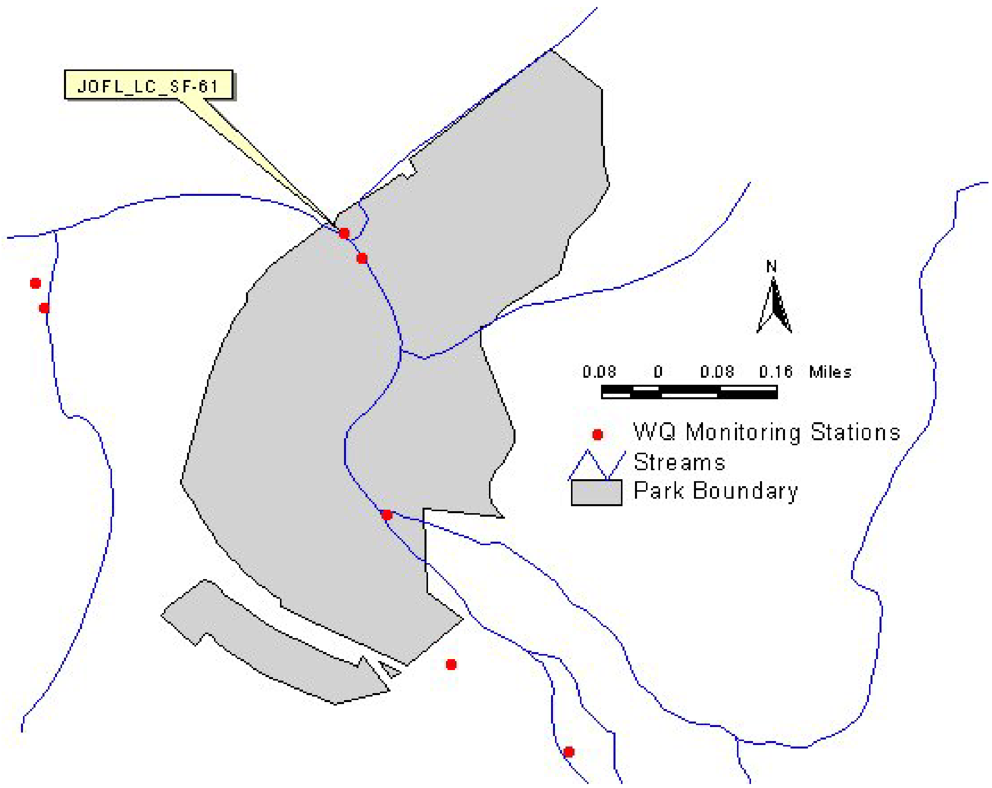
Based upon an analysis of the data, only one sample (specific conductivity) for one date (August 1993) exceeded the criterion value used (in this case, 325 micromhos). The water quality station at which this value was measured (JOFL_LC_61) is shown in Figure 3. This value suggests a possible problem with mine drainage, which is also indicated by problematic levels of aluminum, iron, manganese, and pH recorded at this and other stations in the park during the 1980's. (Note: The water quality stations depicted in this Figure 3 are older sampling points used by the National Park Service and others that have since been discontinued).

TMDL Development

The Pennsylvania Department of Environment Protection (DEP) is the agency responsible for conducting total maximum daily load (TMDL) assessments for impaired waters in the Commonwealth of Pennsylvania. A TMDL is essentially a plan of action used to clean up streams that are not meeting water quality standards. The plan includes pollution source identification and strategy development for contaminant source reduction or elimination. As described earlier, the entire length of the South Fork Little Conemaugh River contained within the park (see Figure 2) has been 303d-listed for pH and metals impairments due to abandoned mine drainage. The TMDL assessment for this reach is currently planned to be completed no later than 2015.

Figure 3. Location of historic water quality monitoring stations.



Presence of Water Quality Monitoring Sites

At present, there are no long-term water quality monitoring stations located in or near the park. However, as part of an ongoing "Level 1" monitoring project being completed for the National Park Service, Penn State University is collecting water quality data at various locations within the park boundary. More specifically, samples are being taken at 5 different locations along the South Fork Little Conemaugh River that flows through the site and some of its tributaries. Data being collected include in-stream measurements of alkalinity, pH, specific conductivity, dissolved oxygen, temperature, instantaneous stream discharge, selected toxics (e.g., cyanide and mercury), nutrients (N and P), turbidity, and fecal coliform.

Recommendations for Future Monitoring

Based upon the analyses of sample data from the mid-1990s, it appears that there are still some problems related to mine drainage in the park. This is supported by the fact that the entire length of the South Fork Little Conemaugh has been 303d-listed for mine drainage-related impairments. Water quality is currently being monitored at several locations in the park as described earlier. Additional monitoring data collection in this section may or may not be needed depending upon the outcome of this work.

Literature Cited

National Park Service. 1999. Baseline Water Quality Data Inventory and Analysis: Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial, Tech. Report NPS/NRWRD/NRTR-99/205, 1193 pp.

Sheeder, S. A. and B.M. Evans, 2004. Estimating Nutrient and Sediment Threshold Criteria for Biological Impairment in Pennsylvania Watersheds. Journal of the American Water Resources Association (JAWRA) 40(4): 881-888.

USEPA (U.S. Environmental Protection Agency), 2002a. List of Drinking Water Contaminants & MCLs. EPA 816-F-02-013, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2002b. Implementation Guidance for Ambient Water Quality Criteria for Bacteria. EPA-823-B-02-003, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2002c. National Recommended Water Quality Criteria: 2002. EPA-822-R-02-047, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 1986. Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003, U.S. Environmental Protection Agency, Washington, D.C.

WATER QUALITY SUMMARY

for

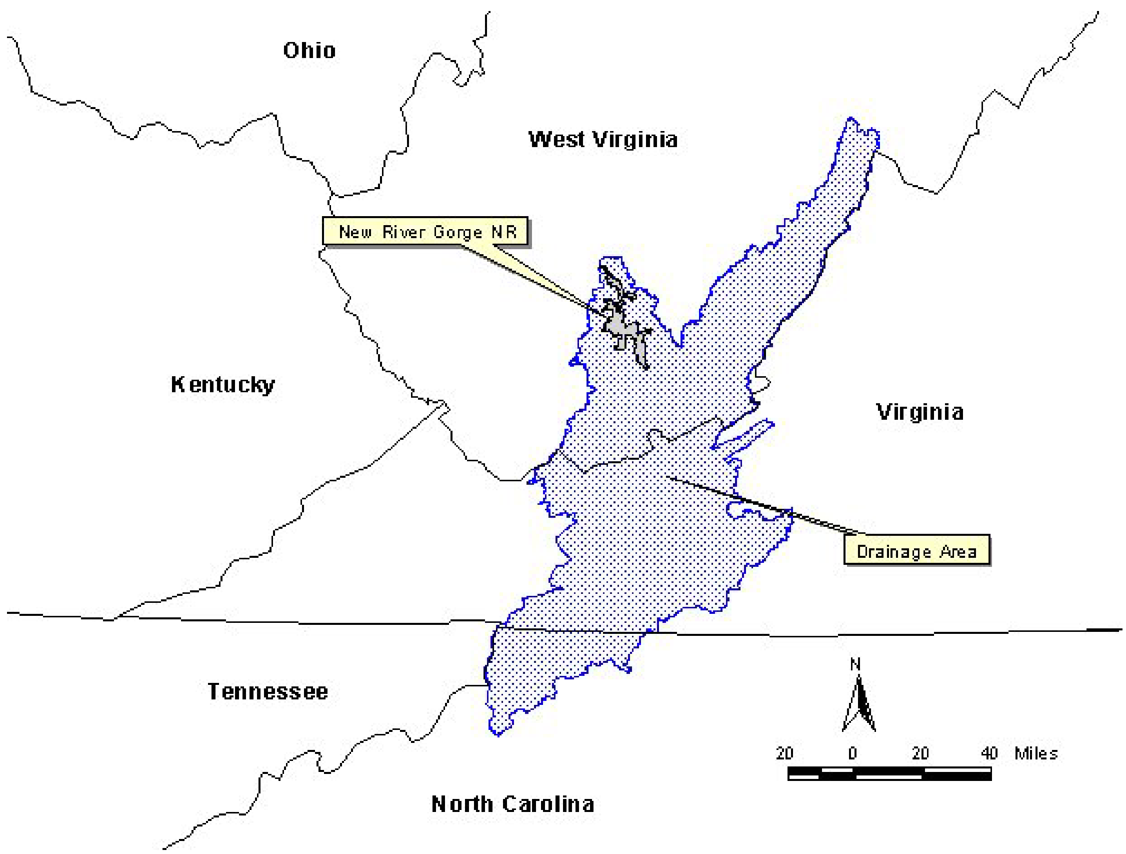
NEW RIVER GORGE NATIONAL RIVER

September 2004

Overview of Park/Watershed Characteristics

The park is approximately 72,332 acres (113 mi^2) in size, and is comprised almost entirely of woodlands with only scattered parcels of open land located primarily in the southern (upstream) portion of the park. The drainage area within which the park is located (as defined by the northernmost edge of the park) is approximately 4,449,482 acres (6,952 mi^2) in size (see Figure 1). This drainage area includes the Bluestone River and Greenbrier River watersheds in West Virginia, and extends through Virginia into North Carolina.

Figure 1. Location of park and drainage area.



As measured at the USGS gage located about 19 miles upstream from the northern edge of the park (3185400), the mean daily stream flow on an annual basis of the New River within the park is about 8461 cfs. Temporal variations in flow on a mean annual basis are depicted in Figure 2. For the purposes of this analysis, various sub-watersheds within the larger watershed have also been defined based on the location of other USGS gages as shown in Figure 3. Table 1 presents information on the relative contributions of each of these smaller sub-watersheds in terms of area and mean annual flows. (One of these gages is also used in the estimation of nutrient and sediment loading rates as described later in this report). Sub-area 1 is essentially the drainage area for the upper reaches of Piney Creek; Sub-area 2 is the Greenbrier River drainage area starting about 5 miles upstream of the confluence with the New River; and Sub-area 3 contains the Bluestone River watershed, as well as all of the New River drainage area upstream of the confluence of the New, Bluestone, and Greenbrier Rivers.

Figure 2. Representative mean annual hydrograph for the New River at USGS gage (3185400) near Thurmond, WV (from New River Gorge National River Horizon report).

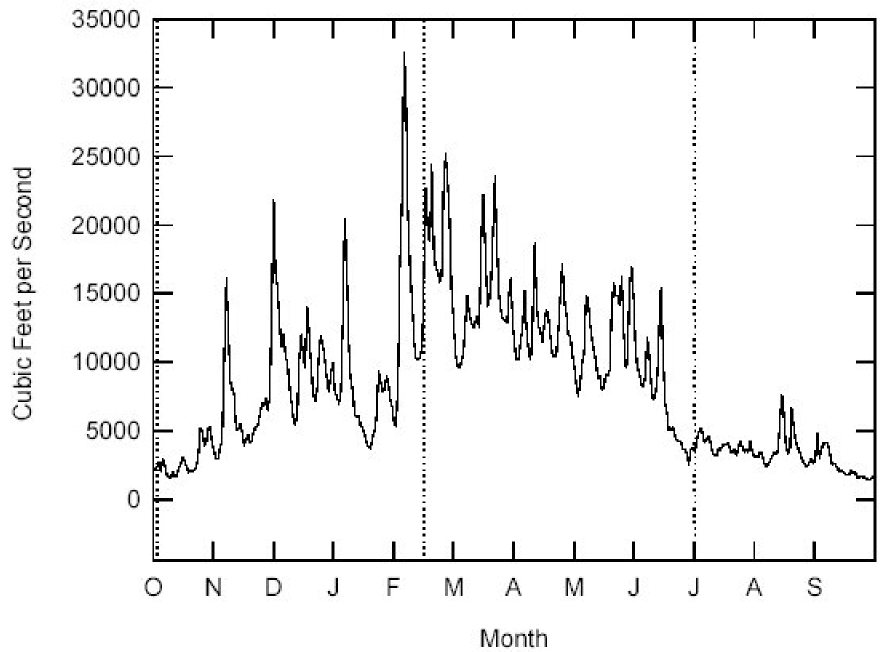


Figure 3. Location of sub-areas with associated USGS gages.

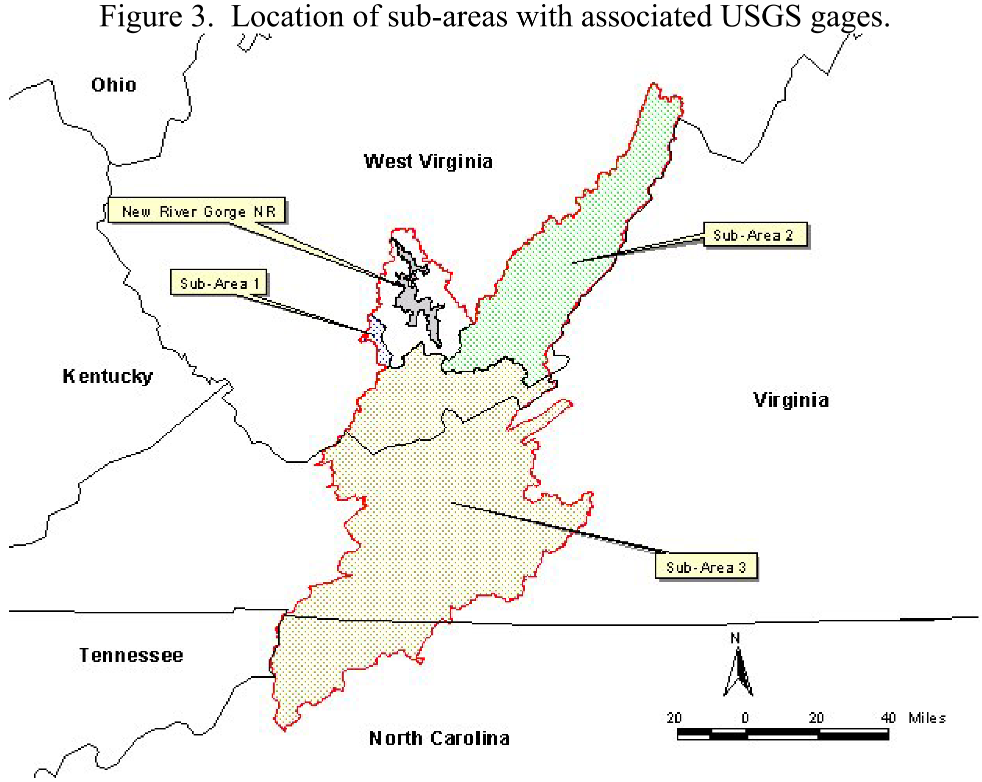


Table 1. Flow characteristics of sub-watersheds.

Watershed	USGS Gage	Mean Daily Flow (cfs)	% of Total Drainage Area	% of Contributed Mean Annual Flow
Entire area	3185400*	8461*	92.3*	100*
Sub-area 1	3185000	62	1.4	0.7
Sub-area 2	3184000	2246	42.6	26.5
Sub-area 3	3180000	5601	44.3	66.2

(*Note: For the purposes of this calculation, it is assumed that the flow at USGS gage 3185400 is more or less representative of flow at the lowermost edge of the park. This gage, however, is located about 19 miles upstream of the park boundary. Therefore, the drainage area defined by this gage is less than the actual drainage area for the park)

Historical Water Quality Overview

Detailed analyses of water quality within and around the New River Gorge NR, as well as other national parks, has previously been prepared by the Water Resources Division (WRD) of the National Park Service (NPS, 1995). These reports are typically referred to as "Horizon" reports after the contractor that performed most of the analyses (Horizon Systems Corporation). For the New River Gorge NR, a Horizon report was done for the period 1946-1995 using data for 146 water quality monitoring stations (both active and inactive) in and around the park. Fifty-nine of these stations were located within the park boundary. The study area used in this particular assessment roughly comprised a buffer zone that extended out about 5-10 miles from the edge of the park, and included that portion of the New River flowing through the park; portions of the Greenbrier River, New River, and Bluestone River/Lake just to the south of the park; and a number of smaller streams in the immediate vicinity of the park.

In the Horizon report, it was noted that during the 1946-1995 period, stream observations for a total of 21 parameters exceeded the screening criteria used in the study at least once within the study area boundary used. These parameters included dissolved oxygen, pH, antimony, arsenic, beryllium, cadmium, chromium, copper, cyanide, fluoride, lead, mercury, nickel, silver, sulfate, thallium, zinc, bacteria (total coliform and fecal coliform), and turbidity. The criteria used for various parameters included EPA criteria for the protection of freshwater aquatic life and drinking water, and WRD screening limits for freshwater bathing. Based on the results of this study, it was believed by the authors that surface waters within the area studied had been impacted by bacteria and trace metals, and that such impacts were primarily due to municipal and residential development, other wastewater discharges, recreational uses, farming and livestock grazing, and abandoned and active coal mines. However, given the fact that the assessment was done using some very old monitoring data (i.e., back to 1946 in some cases), it is likely that some of the problems identified have since been rectified (e.g., those related to municipal discharges), and that other problems related to coal mining have diminished somewhat due to the fact that there are far fewer active mines now than there were during the time period studied.

Many of the contaminant exceedances described above are probably not particularly important today either because of very low exceedance percentages (e.g., 5% of the total observations or less), or because such exceedances occurred over 20 years ago (this is particularly true in the cases of turbidity, fluoride, sulfate, cyanide, antimony, arsenic, beryllium, chromium, copper, nickel, silver, and zinc). Based on the above limitations, it appears that the primary pollutants/parameters of concern now (particularly in the part of the New River that flows through the park, as well as the smaller streams that drain to the New River in and near the park) are dissolved oxygen, pH, bacteria (total coliform and fecal coliform), cadmium, lead, mercury, and thallium. These concerns are borne out by the fact that many of the surface water bodies in and around the New River NR have been included on West Virginia's 303d list (as discussed in a later section) for impairments due to mine drainage and fecal coliform.

Specially Designated Surface Water Bodies

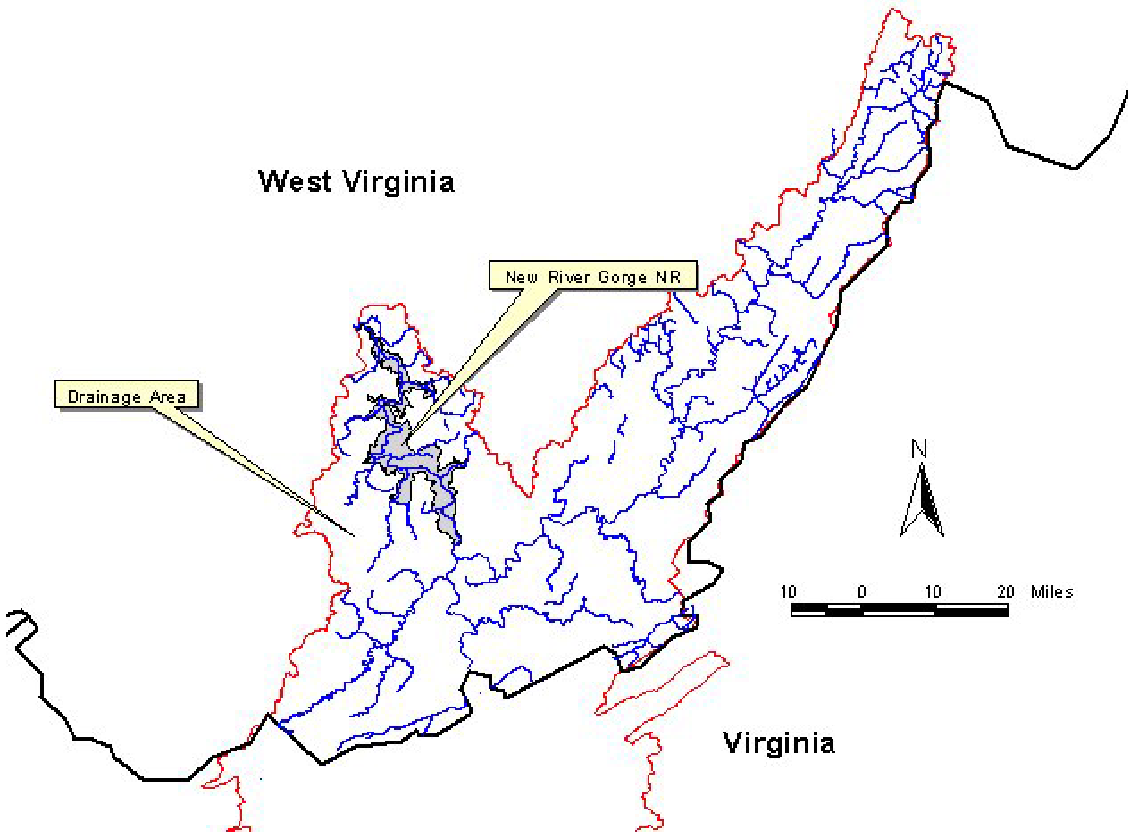
There are over 4100 miles of streams in the West Virginia portion of the watershed depicted in Figure 1 that serves as the drainage area for the New River Gorge NR. Of this total, approximately a quarter have been designated as "high quality" (see Figure 4). Of the approximately 166 miles of streams contained with the park boundary, about half of them (approximately 84 stream miles) have been designated as being "high quality", including the New River, Wolf Creek, Dunloup Creek, Piney, Glade Creek (2 separate streams), Pinch Creek, Fall Branch, Meadow Creek, Laurel Creek, Manns Creek, Keeney Creek, and Mill Creek (see Figure 5). Table 2 provides information on the status of all streams falling within the park boundary in terms of meeting their designated uses, and Table 3 provides descriptions of each of these uses.

As defined by the State of West Virginia, "high quality waters" are those waters whose quality is equal to or better than the minimum levels necessary to achieve the national water quality goal uses. Such waters require what is defined as "Tier 2" protection, which requires that the existing high quality waters of the state must be maintained at their existing high quality unless it is determined after satisfaction of the intergovernmental coordination of the state's continuing planning process and opportunity for public comment and hearing that allowing lower water quality is necessary to accommodate important economic or social development in the area in which the waters are located. If limited degradation is allowed, it shall not result in injury or interference with existing stream water uses or in violation of state or federal water quality criteria that describe the base levels necessary to sustain the national water quality goal uses of protection and propagation of fish, shellfish and wildlife and recreating in and on the water.

High quality waters may include but are not limited to the following:

- Streams designated by the West Virginia Legislature under the West Virginia Natural Stream Preservation Act, pursuant to W. Va. Code §22-13-5;
- Streams listed in West Virginia High Quality Streams, Fifth Edition, prepared by the Wildlife Resources Division, Department of Natural Resources (1986); and
- Streams or stream segments which receive annual stockings of trout but which do not support year-round trout populations.

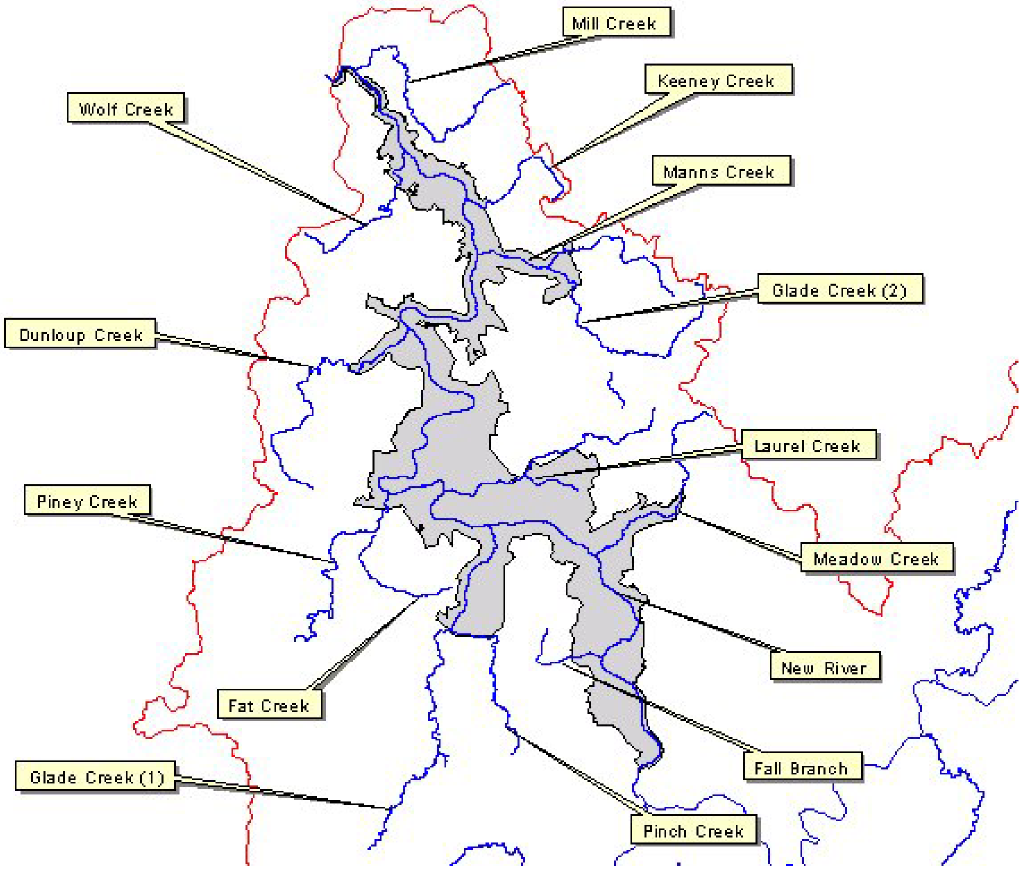
Figure 4. Location of high quality streams in West Virginia portion of the drainage area for the New River Gorge NR.



Current Listing of Water Quality Impairments

As shown in Figure 6, a number of surface water bodies within the drainage area of the New River Gorge NR have been identified as being impaired on West Virginia's 303d list. As can be seen from Figure 4, many of the impaired streams have also been designated as "high quality" streams. Most of the impaired surface waters in the larger watershed are listed for problems related to dissolved aluminum, iron, manganese, pH, fecal coliform, or for being otherwise biologically impaired (i.e., CNA-Biological). Table 4 provides information on the impaired surface water bodies either in or immediately adjacent to the New River Gorge NR, and Figure 7 depicts the location of these streams. In the cases where the "causes" have been listed as "unknown" for fecal coliform, it is very likely that the problems are due to untreated wastewater or manure runoff from pasture land in rural areas. Out of approximately 166 miles of streams located within the park, about 44% (73 miles) have been designated as being water quality-impaired. In cases where the causes of biological impairments (CNA-Biological) have been attributed to "unknown" sources, it is possible that such impairments may be due to mine drainage (as in the cases of the unnamed tributary of Glade Creek and Brooks Branch) or urban discharges/runoff (as in the cases of Arbuckle Creek and Wolf Creek).

Figure 5. Location of designated "high quality" streams within the park boundary



In addition to the impaired streams located within the park boundary, Figure 7 also depicts three other streams located in close proximity to the park where impairments have been noted. These include Madam Creek, Laurel Creek, and Floyd Creek. Madam Creek has been listed for fecal coliform problems due to unknown sources. Laurel and Floyd Creeks have both been listed for iron and manganese impairments from mine drainage. Floyd Creek has also been listed for biological impairments (CNA-Biological) due to unknown causes.

Current Water Quality Trends and Loading Rates

Using more recently-compiled water quality data, mean annual concentration values for selected parameters were compared with criteria similar to those used in the earlier Horizon reports to assess whether potential water quality problems identified in the past still exist. These selected parameters were based on various factors, including past problems described in the Horizon report, problems identified in the 303d listings, and the list of core parameters to be used as "vital sign" indicators as identified by WRD. Temperature is also listed as one of the core parameters, but was not included here for several reasons. First, there are no established temperature criteria to use to evaluate the condition of the aquatic system. Secondly, trends in temperature could be evaluated but the results may prove misleading due to natural long-term air temperature trends and the relationship between air and water temperature (i.e. gradual warming

Table 2. Status of designated uses of streams within the park boundary.

Stream	Stream Miles or Lake Size	Category	Agricultural and Wildlife Uses	Public Water Supply	Trout Waters	Warm Water Fishery Streams	Water Contact Recreation	High Quality
Wolf Creek	2.27	5	Fully Supporting	Not Supporting	Not Supporting	N/A	Not Supporting	Yes
House Branch	0.32	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Fern Creek	1.05	3	Insufficient Information	Insufficient Information	N/A	Insufficient Information	Insufficient Information	Yes
Butcher Branch	1.60	1	Fully Supporting	Fully Supporting	N/A	Fully Supporting	Fully Supporting	No
Craig Branch	1.91	2	Fully Supporting	Fully Supporting	N/A	Insufficient Information	Fully Supporting	No
Short Creek	0.74	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Keeney Creek	0.92	5	Fully Supporting	Not Supporting	N/A	Fully Supporting	Not Supporting	No
Coal Run	1.13	5	Insufficient Information	Not Supporting	N/A	Insufficient Information	Not Supporting	No
Manns Creek	5.11	1	Fully Supporting	Fully Supporting	N/A	Fully Supporting	Fully Supporting	Yes
Boley Lake	17.31	2	N/A	Not Assessed	N/A	Insufficient Information	Fully Supporting	No
Glade Creek	1.86	2	Fully Supporting	Fully Supporting	Not Assessed	Fully Supporting	Fully Supporting	No
UNT/Glade Creek RM 2	0.28	5	Not Supporting	Not Supporting	N/A	Not Supporting	Not Supporting	No
Ephraim Creek	1.67	1	Fully Supporting	Fully Supporting	N/A	Fully Supporting	Fully Supporting	No
Fire Creek	1.61	2	Fully Supporting	Fully Supporting	N/A	Insufficient Information	Fully Supporting	No
Rush Run	0.54	2	Fully Supporting	Fully Supporting	N/A	Insufficient Information	Fully Supporting	No
Arbuckle Creek	1.53	5	Fully Supporting	Not Supporting	N/A	Not Supporting	Not Supporting	No
Mollys Creek	1.20	3	Insufficient Information	Insufficient Information	N/A	Insufficient Information	Insufficient Information	No
Little Stony Creek	0.35	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Big Stony Creek	0.49	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Dunloup Creek	3.89	4A	Fully Supporting	Not Supporting	Not Supporting	N/A	Not Supporting	Yes
Camp Creek	0.87	2	Fully Supporting	Fully Supporting	N/A	Insufficient Information	Fully Supporting	No
Meadow Creek	0.50	4A	Not Supporting	Not Supporting	N/A	Not Supporting	Not Supporting	No
Cedar Branch	0.18	2	Fully Supporting	Fully Supporting	N/A	Insufficient Information	Fully Supporting	No
Barren Branch	0.07	2	Fully Supporting	Fully Supporting	N/A	Insufficient Information	Fully Supporting	No
White Oak Creek	0.06	3	Not Assessed	Insufficient Information	N/A	Insufficient Information	Insufficient Information	No
Buffalo Creek	1.59	1	Fully Supporting	Fully Supporting	Fully Supporting	N/A	Fully Supporting	No
Slater Creek	1.88	5	Fully Supporting	Not Supporting	N/A	Fully Supporting	Not Supporting	No
Slater Creek	1.88	1	Fully Supporting	Fully Supporting	N/A	Fully Supporting	Fully Supporting	No
Dowdy Creek	3.23	2	Fully Supporting	Fully Supporting	N/A	Insufficient Information	Fully Supporting	No
Piney Creek	0.72	5	Fully Supporting	Not Supporting	Insufficient Information	N/A	Not Supporting	Yes
McCreery Hollow	1.48	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Batoff Creek	1.07	5	Not Supporting	Not Supporting	N/A	Not Supporting	Not Supporting	No
Laurel Creek	4.21	1	Fully Supporting	Fully Supporting	Fully Supporting	N/A	Fully Supporting	Yes
Little Laurel Creek	2.72	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	Yes
Richlick Branch	2.31	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Bucklick Branch	1.98	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Sandylick Branch	1.37	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Mill Creek	1.37	2	Fully Supporting	Fully Supporting	N/A	Insufficient Information	Fully Supporting	No
River Branch	1.12	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Spruce Fork	0.04	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No

Table 2. Status of designated uses of streams within the park boundary (cont.).

Stream	Stream Miles or Lake Size	Category	Agricultural and Wildlife Uses	Public Water Supply	Trout Waters	Warm Water Fishery Streams	Water Contact Recreation	High Quality
Slate Fork	0.08	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Glade Creek	5.73	2	Fully Supporting	Insufficient Information	Fully Supporting	N/A	Insufficient Information	Yes
Bills Branch	0.88	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Second Fork	1.12	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Polls Branch	1.67	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Kates Branch	2.25	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Pinch Creek	0.86	1	Fully Supporting	Fully Supporting	Fully Supporting	Fully Supporting	Fully Supporting	Yes
Camp Creek	1.83	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Panther Branch	1.49	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Davis Branch	0.90	1	Fully Supporting	Fully Supporting	N/A	Fully Supporting	Fully Supporting	No
Meadow Creek	5.38	5	Fully Supporting	Not Supporting	Fully Supporting	N/A	Not Supporting	Yes
Lefthand Fork	0.59	1	Fully Supporting	Fully Supporting	N/A	Fully Supporting	Fully Supporting	No
Beelick Branch	0.71	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Claypool Branch	0.26	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Coon Creek	0.11	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Sewell Branch	1.72	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Farleys Creek	1.68	5	Fully Supporting	Fully Supporting	N/A	Not Assessed	Fully Supporting	No
Lick Creek	0.80	5	Fully Supporting	Not Supporting	N/A	Fully Supporting	Not Supporting	Yes
Laurel Creek	0.19	1	Fully Supporting	Fully Supporting	N/A	Fully Supporting	Fully Supporting	No
Fall Branch	1.35	2	Fully Supporting	Fully Supporting	N/A	Insufficient Information	Fully Supporting	No
Mill Branch	1.09	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Cotes Branch	1.00	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Jerrys Hollow	1.19	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Owens Branch	0.16	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Collins Hollow	0.15	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Kates Branch	1.67	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Big Branch	1.18	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	Yes
Brooks Branch	0.16	5	Fully Supporting	Insufficient Information	N/A	Not Supporting	Insufficient Information	No
Brier Branch	0.05	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Tug Creek	0.04	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Penfield Branch	0.18	3	Not Assessed	Not Assessed	N/A	Not Assessed	Not Assessed	No
Marr Branch	0.65	5	Fully Supporting	Not Supporting	N/A	Not Supporting	Not Supporting	No
New River (Lower)	49.80	5	Fully Supporting	Not Supporting	N/A	Not Supporting	Not Supporting	Yes
New River (Lower)	8.00	5	Fully Supporting	Fully Supporting	N/A	Not Supporting	Fully Supporting	Yes

Table 3. Various “use-related” descriptions for streams used in West Virginia.

West Virginia 305b Category Descriptions

Category 1: Fully Supporting all designated uses.
Category 2: Fully supporting some designated uses, but no or insufficient information exists to assess the other designated uses.
Category 3: Insufficient or no information exists to determine if any of the uses are being met.
Category 4a: Waters that already have an approved TMDL but are still not meeting standards.
Category 5: Waters that have been assessed as impaired and are expected to need a TMDL.

West Virginia Use Attainment Descriptions

Fully Supporting: The sampled data suggest that stream can attain the designated use.
Insufficient Information: Some data suggest that stream may or may not attain the designated use. Not enough samples to conclude whether or not the stream can attain the designated use.
Not Supporting: The sample data suggest that stream cannot attain the designated use.
Not Assessed: No data have been collected.
N/A: No assessment information provided.

West Virginia Special Waters Designated Use Descriptions

Public Water Supply: This category is used to describe waters which, after conventional treatment, are used for human consumption. This category includes streams on which the following are located:

a) All community domestic water supply systems;
b) All non-community domestic water supply systems (i.e., hospitals, schools, etc.);
c) All private domestic water systems;
d) All other surface water intakes where the water is used for human consumption. The manganese human health criteria shall not apply where the discharge point of the manganese is located more than five miles upstream from a known drinking water source.

Agricultural and Wildlife Uses:

a) Irrigation – This category includes all stream segments used for irrigation.
b) Livestock watering – This category includes all stream segments used for livestock watering.
c) Wildlife – This category includes all stream segments and wetlands used by wildlife.

Water Contact Recreation: This category includes swimming, fishing, water skiing and certain types of pleasure boating such as sailing in very small craft and outboard motor boats.

Warm Water Fishery Streams: Streams or stream segments which contain populations composed of all warm water aquatic life.

Trout Waters: Streams or stream segments which sustain year-round trout populations. Excluded are those streams or stream segments which receive annual stockings of trout but which do not support year-round trout populations.

High Quality Waters: Waters whose quality is equal to or better than the minimum levels necessary to achieve the national water quality goal uses.

of mean annual water temperature may reflect recent warming of the climate, and not watershed disturbance)..

Temporal trends for selected water quality parameters were also determined to provide a sense of potential changes in such parameters over time (i.e., are problems getting worse or better?). Temporal trends were evaluated for each constituent that exceeded concentration criteria during the period of analysis (1990-present). To determine the existence of a temporal trend, concentration values were plotted against date and fit with a linear trendline in MS Excel. Additionally, loading rates for various water quality parameters were estimated for the Greenbrier River watershed (see “Sub-Area 2” in Figure 3) to provide another measure of potential water quality problems. Unfortunately, it was not possible to estimate similar loading rates for the park or any other area due to the lack of water quality information at USGS gage locations.

Based upon information provided in previous sections, water quality statistics and trends were determined for total phosphorus, specific conductivity, pH, fecal coliform, iron, aluminum, manganese, and dissolved oxygen where the appropriate data were available (see Table 5). These parameters were selected because they are commonly used to assess certain aspects of the hydrologic system, and are briefly discussed below. In all cases, an attempt was made to use any sample data collected from 1990 up to the present. However, as can be seen from Table 5, data were generally not available more recently than 1995, except for a few grab samples on some streams taken during a 1-month period in 1999. The water quality stations for which data were compiled for this analysis are shown in Figure 8.

Specific Conductivity is the ability of a substance to conduct an electrical current across a given length at a specified temperature. Specific Conductivity can be used as an indicator of water quality because pure water has a very low electrical conductance. As concentrations of different ions dissolved in water increase, so does the conductivity. Therefore, conductivity is directly related to the amount of charged particles (i.e. heavy metals, clay particles, etc.) contained within a water sample. While there are no set conductivity criteria for fresh water, specific conductance is linearly related to the concentration of total dissolved solids in a sample. For the purposes of this investigation,

$$0.65*K = S$$

where K is conductance (micromhos) and S is dissolved solids (mg/L). The EPA has a recommended criterion of 500 mg/L for dissolved solids in drinking water (US EPA, 2002a). This corresponds to a specific conductivity of 325 micromhos, given the equation above.

pH is one of the most general indicators of water quality. The natural logarithm of hydrogen ion concentration in solution, pH ranges from 0-14 with 7 being neutral. pH values ranging from approximately 6-8 naturally occur in freshwater aquatic systems. The EPA-established criterion for aquatic life protection includes pH values between 6.5 and 9.0. For the purposes of this investigation, recorded values outside of this range were flagged as an indication of impairment.

Figure 6. Location of impaired surface water bodies on 303d list.

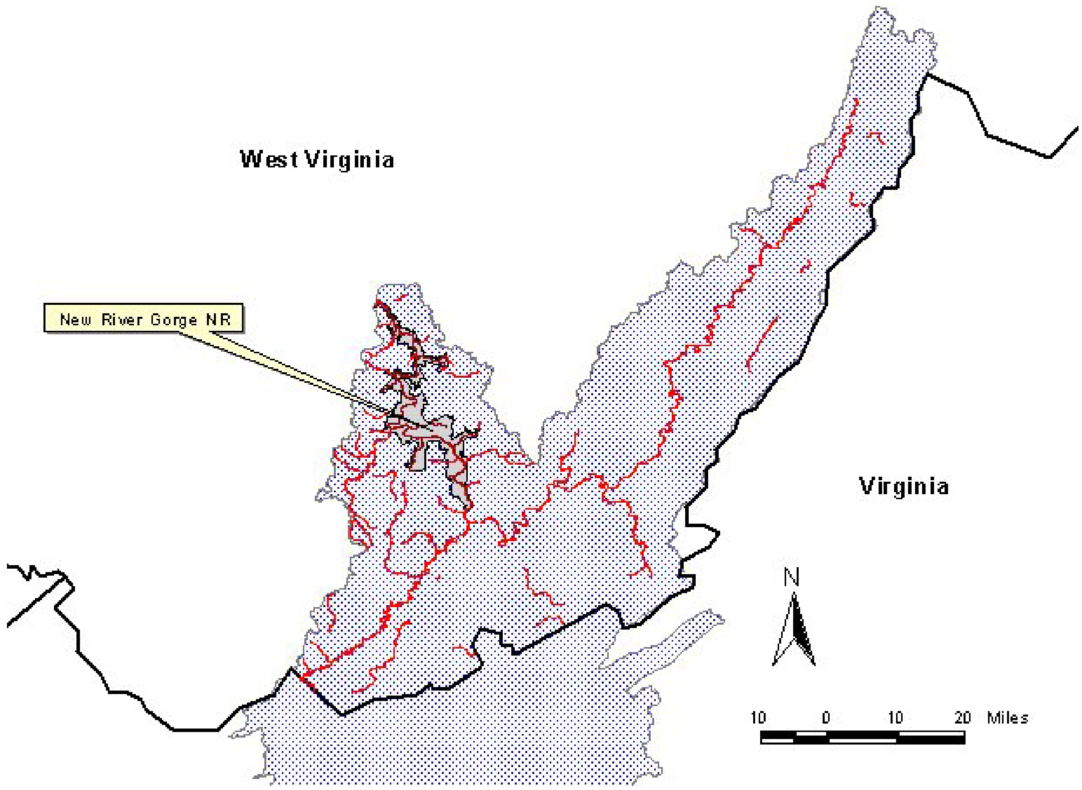


Table 4. Sources and causes of listed impairments.

Surface Water Body	Cause[1]	Source	On 2002 List?
New River	Dissolved Al, FC	Unknown	No, No
Marr Branch	CNA-B, FC	Unknown	Yes, Yes
Wolf Creek	CNA-B, FC	Unknown	Yes, No
Kenney Creek	FC	Unknown	Yes
Coal Run	FC	Unknown	Yes
Unnamed Trib. Of Glade Creek	pH	Unknown	Yes
Arbuckle Creek	CNA-B, FC	Unknown	Yes, Yes
Slater Creek	FC	Unknown	No
Piney Creek	FC	Unknown	Yes
Batoff Creek[2]	Fe, Mg, pH	Mine Drainage	Yes (all)
Meadow Creek	FC	Unknown	Yes
Farley Creek	CNA-B	Unknown	Yes
Lick Creek	FC	Unknown	Yes
Brooks Branch	CNA-B	Unknown	Yes

Note: 1) Dissolved Al = dissolved aluminum, CNA-B = CNA-Biological, FC = Fecal Coliform, and 2) Batoff Creek was listed in 2002 for Al, but was de-listed due to change in criteria for aluminum.

Table 5. Results of analyses based on recently-compiled water quality data at stations in and around New River Gorge NR.

Chemical Characteristic	Station ID	Station Name	Exceedances	No. Obs.	% Exceed	Begin Date	End Date	Min. Value	Max. value	Avg. Value	Trend
Aluminum (UG/L AS AL)	550480	Greenbrier River near Hilldale, WV	4	60	7%	Jan-90	May-95	50	2000	236.93	NA
Fecal Coliform (CFU/100mL)	550480	Greenbrier River near Hilldale, WV	3	57	5%	Jan-90	Apr-95	2	420	48.46	NA
Iron (ug/L as Fe)	550480	Greenbrier River near Hilldale	1	60	2%	Jan-90	May-95	15	2000	175.88	NA
Manganese (ug/L as Mn)	550480	Greenbrier River near Hilldale, WV	1	60	2%	Jan-90	May-95	5	60	11.07	NA
pH (Standard Units)	550480	Greenbrier River near Hilldale, WV	1	58	2%	Jan-90	May-95	6.3	8.2	7.48	NA
pH (Standard Units)	550480	Greenbrier River near Hilldale, WV	1	14	7%	Jan-90	Jul-93	5.9	8.1	7.27	NA
Aluminum (UG/L AS AL)	550546	Piney Creek near Prince, WV	2	4	50%	Mar-90	Dec-90	200	2700	1082.50	NA
Fecal Coliform (CFU/100mL)	550546	Piney Creek near Prince, WV	2	4	50%	Jul-94	Jul-94	100	650	312.50	NA
Manganese (ug/L as Mn)	550546	Piney Creek near Prince, WV	2	4	50%	Mar-90	Dec-90	5	60	32.50	NA
Specific Conductance	550546	Piney Creek near Prince, WV	1	4	25%	Mar-90	Dec-90	126	339	242.00	NA
Specific Conductance	550546	Piney Creek near Prince, WV	4	4	100%	Jul-94	Jul-94	438	452	447.75	NA
Fecal Coliform (CFU/100mL)	550547	Piney Creek below Raleigh, WV	8	13	62%	Jul-94	Jun-95	100	2700	670.00	-
Specific Conductance	550547	Piney Creek below Raleigh, WV	5	5	100%	Jul-94	Jul-94	398	467	420.60	NA
Aluminum (UG/L AS AL)	550550	Dunloup Creek near Thurmond, WV	1	4	25%	Mar-90	Dec-90	260	1400	592.50	NA
Manganese (ug/L as Mn)	550550	Dunloup Creek near Thurmond, WV	2	4	50%	Mar-90	Dec-90	5	220	83.75	NA
Specific Conductance	550550	Dunloup Creek near Thurmond, WV	3	4	75%	Mar-90	Dec-90	208	629	424.00	NA
Aluminum (UG/L AS AL)	550552	Wolf Creek near Fayetteville, WV	3	4	75%	Mar-90	Dec-90	210	2200	1100.00	NA
Manganese (ug/L as Mn)	550552	Wolf Creek near Fayetteville, WV	1	4	25%	Mar-90	Dec-90	5	85	28.75	NA
Specific Conductance	550552	Wolf Creek near Fayetteville, WV	1	4	25%	Mar-90	Dec-90	150	680	353.75	NA
Aluminum (UG/L AS AL)	550722	Arbuckle Creek at Thurmond, WV	4	4	100%	Mar-90	Dec-90	880	1700	1345.00	NA
Manganese (ug/L as Mn)	550722	Arbuckle Creek at Thurmond, WV	3	4	75%	Mar-90	Dec-90	15	600	187.50	NA
Specific Conductance	550722	Arbuckle Creek at Thurmond, WV	4	4	100%	Mar-90	Dec-90	330	696	524.00	NA
Aluminum (UG/L AS AL)	550861	Meadow Crk at Town of Meadow Crk	1	4	25%	Mar-90	Dec-90	100	1400	667.50	NA
Aluminum (UG/L AS AL)	550863	Laurel Creek at Quinnmont, WV	2	4	50%	Mar-90	Dec-90	180	975	548.75	NA
Specific Conductance	550864	Farley Crk / Sandstone Falls St. Park	3	4	75%	Mar-90	Dec-90	160	555	351.50	NA
Aluminum (UG/L AS AL)	550936	Marr Branch near Fayetteville, W. Va.	2	4	50%	Mar-90	Dec-90	150	900	543.75	NA
Dissolved Oxygen (mg/L)	550936	Marr Branch near Fayetteville, W. Va.	1	4	25%	Mar-90	Dec-90	3.8	10.6	7.90	NA
Manganese (ug/L as Mn)	550936	Marr Branch near Fayetteville, W. Va.	4	4	100%	Mar-90	Dec-90	55	325	143.75	NA
Specific Conductance	550936	Marr Branch near Fayetteville, W. Va.	1	4	25%	Mar-90	Dec-90	107	654	287.75	NA
Aluminum (UG/L AS AL)	550964	Coal Run below Cunard, W. Va.	1	5	20%	Jan-90	Dec-90	160	1500	602.00	NA
Fecal Coliform (CFU/100mL)	550964	Coal Run below Cunard, W. Va.	1	1	100%	Jan-90	Jan-90	430	430	430.00	NA
Manganese (ug/L as Mn)	550964	Coal Run below Cunard, W. Va.	1	5	20%	Jan-90	Dec-90	5	450	106.00	NA
Specific Conductance	550964	Coal Run below Cunard, W. Va.	3	5	60%	Jan-90	Dec-90	193	491	350.80	NA
Aluminum (UG/L AS AL)	550965	Keeney Creek in Winona, W. Va.	2	4	50%	Mar-90	Dec-90	270	3300	1317.50	NA
Aluminum (UG/L AS AL)	550966	Laurel Creek at Sandstone, W. Va.	1	4	25%	Mar-90	Dec-90	250	1100	575.00	NA
Aluminum (UG/L AS AL)	550967	Lick Creek near Sandstone, W. Va.	1	4	25%	Mar-90	Dec-90	220	1400	622.50	NA
Specific Conductance	550967	Lick Creek near Sandstone, W. Va.	1	4	25%	Mar-90	Dec-90	111	335	200.75	NA
Aluminum (UG/L AS AL)	550968	Mill Crk near Grandview St Park, WV	1	4	25%	Mar-90	Dec-90	220	910	462.50	NA
Aluminum (UG/L AS AL)	550970	Buffalo Creek near Thayer, W. Va.	1	4	25%	Mar-90	Dec-90	190	1100	515.00	NA
Aluminum (UG/L AS AL)	550971	Manns Crk in Babcock St. Park, WV	3	4	75%	Mar-90	Dec-90	150	1600	897.50	NA
Manganese (ug/L as Mn)	KN-000-0046	New River north of Cotton Hill, W.Va.	1	1	100%	Aug-99	Aug-99	50.5	50.5	50.50	NA
Fecal Coliform (CFU/100mL)	KN-009-0001	Marr Branch north of Fayetteville, WV	1	1	100%	Sep-99	Sep-99	1800	1800	1800.00	NA
Specific Conductance	KN-009-0001	Marr Branch north of Fayetteville, WV	1	1	100%	Sep-99	Sep-99	503	503	503.00	NA
Specific Conductance	KN-010-0001	Wolf Creek at South Fayette, W.Va.	1	1	100%	Sep-99	Sep-99	656	656	656.00	NA
Fecal Coliform (CFU/100mL)	KN-011-0001	Fern Crk at Canyon Rim Visitor Center	1	1	100%	Aug-99	Aug-99	400	400	400.00	NA

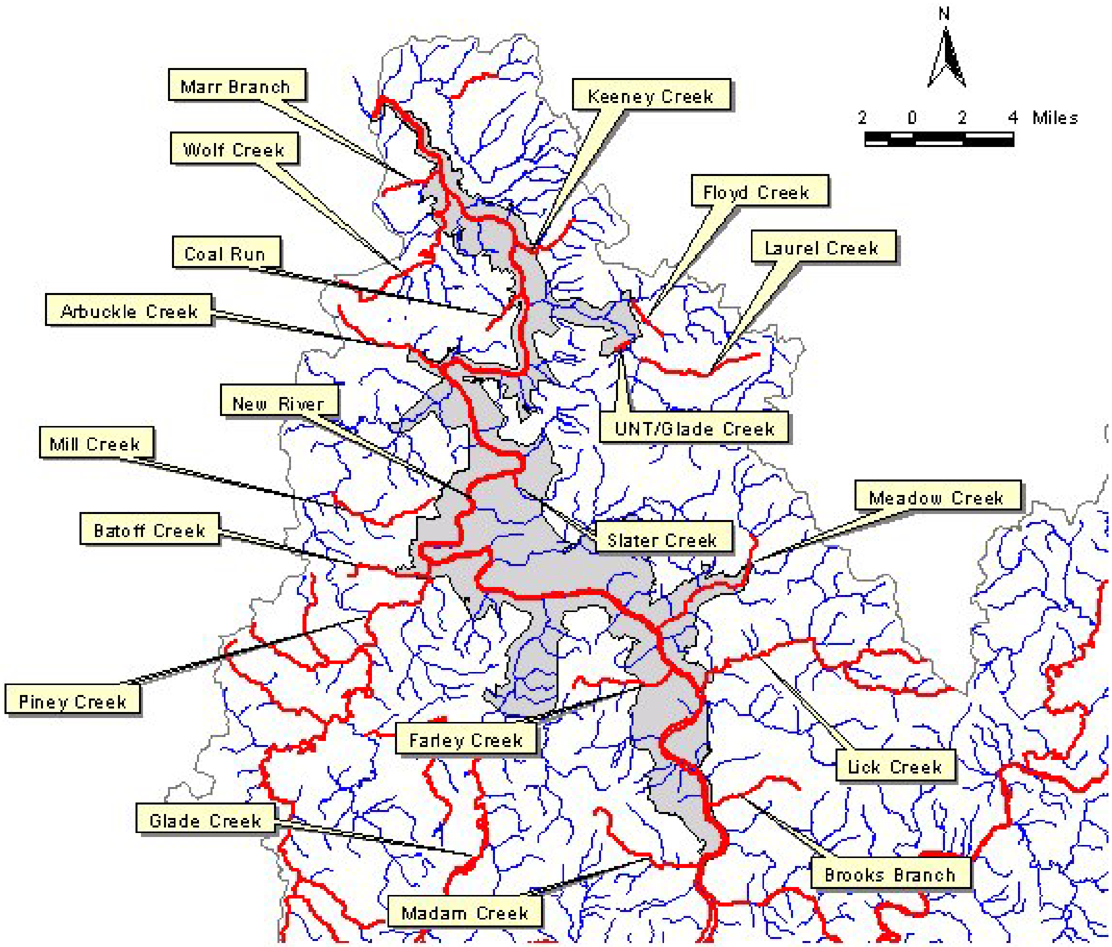
Manganese (ug/L as Mn)	KN-011-0001	Fern Crk at Canyon Rim Visitor Center	1	1	100%	Aug-99	Aug-99	64.4	64.4	64.40	NA
pH (Standard Units)	KN-011-0001	Fern Crk at Canyon Rim Visitor Center	1	1	100%	Aug-99	Aug-99	5.7	5.7	5.70	NA
Iron (ug/L as Fe)	KN-017-0008	Floyd Creek south of Clifftop, W.Va.	1	1	100%	Aug-99	Aug-99	4870	4870	4870.00	NA
Manganese (ug/L as Mn)	KN-017-0008	Floyd Creek south of Clifftop, W.Va.	1	1	100%	Aug-99	Aug-99	3270	3270	3270.00	NA
pH (Standard Units)	KN-017-0008	Floyd Creek south of Clifftop, W.Va.	1	1	100%	Aug-99	Aug-99	6.3	6.3	6.30	NA
Specific Conductance	KN-017-0008	Floyd Creek south of Clifftop, W.Va.	1	1	100%	Aug-99	Aug-99	345	345	345.00	NA
Specific Conductance	KN-022-0001	Dunloup Creek south of Thurmond, W\	1	1	100%	Aug-99	Aug-99	530	530	530.00	NA
Manganese (ug/L as Mn)	KN-022-0006	Meadow Fork SW of Thurmond, W.Va.	1	1	100%	Aug-99	Aug-99	226.1	226.1	226.10	NA
Phosphorus as P (mg/L)	KN-026-0001	Piney Creek at McCreery, W.Va.	1	1	100%	Aug-99	Aug-99	0.688	0.688	0.69	NA
Specific Conductance	KN-026-0001	Piney Creek at McCreery, W.Va.	1	1	100%	Aug-99	Aug-99	528	528	528.00	NA
Fecal Coliform (CFU/100mL)	KN-029-0001	Glade Creek east of Grandview, W.Va.	1	1	100%	Aug-99	Aug-99	400	400	400.00	NA
Fecal Coliform (CFU/100mL)	KN-029-0002	Glade Creek NE of Table Rock, W.Va.	1	1	100%	Aug-99	Aug-99	520	520	520.00	NA
Fecal Coliform (CFU/100mL)	KN-034-0001	Farelys Crk / Sandstone Falls St. Park	1	1	100%	Aug-99	Aug-99	260	260	260.00	NA
Specific Conductance	KN-034-0001	Farelys Crk / Sandstone Falls St. Park	1	1	100%	Aug-99	Aug-99	617	617	617.00	NA
Specific Conductance	KN-035-0001	Lick Creek at Sandstone, W.Va.	1	1	100%	Aug-99	Aug-99	524	524	524.00	NA
Fecal Coliform (CFU/100mL)	KN-042-0001	Brooks Branch at Barksdale, W.Va.	1	1	100%	Sep-99	Sep-99	12400	12400	12400.00	NA
Fecal Coliform (CFU/100mL)	NERI_N01	NEW RIVER AT HINTON VC	4	52	8%	May-90	Jun-95	4	375	55.87	NA
Iron (ug/L as Fe)	NERI_N01	NEW RIVER AT HINTON VC	2	9	22%	Jul-92	Apr-95	35	1122	538.33	NA
pH (Standard Units)	NERI_N01	NEW RIVER AT HINTON VC	1	53	2%	Jul-90	Jun-95	7.2	9.4	8.02	NA
Fecal Coliform (CFU/100mL)	NERI_N03	NEW RIVER AT HINTON STP	10	23	43%	May-90	Sep-92	6	22400	4113.43	-
Fecal Coliform (CFU/100mL)	NERI_N04	NEW RIVER AT SANDSTONE	3	57	5%	May-90	Jun-95	4	2060	95.49	NA
Iron (ug/L as Fe)	NERI_N04	NEW RIVER AT SANDSTONE	3	9	33%	Jul-92	Apr-95	37	1351	592.78	NA
pH (Standard Units)	NERI_N04	NEW RIVER AT SANDSTONE	1	60	2%	Jul-90	Jun-95	7	9.3	8.21	NA
Fecal Coliform (CFU/100mL)	NERI_N05	LICK CREEK	7	58	12%	May-90	Jun-95	8	1000	125.54	-
Iron (ug/L as Fe)	NERI_N05	LICK CREEK	1	8	13%	Jul-92	Apr-95	27	1150	360.50	NA
pH (Standard Units)	NERI_N05	LICK CREEK	1	59	2%	Jul-90	Jun-95	6.8	9.1	8.00	NA
Specific Conductance	NERI_N05	LICK CREEK	12	52	23%	Jun-91	Jun-95	53	440	227.13	+
Fecal Coliform (CFU/100mL)	NERI_N06	MEADOW CREEK	11	58	19%	May-90	Jun-95	3	6000	243.06	+
Iron (ug/L as Fe)	NERI_N06	MEADOW CREEK	1	8	13%	Jul-92	Apr-95	34	1297	324.63	NA
pH (Standard Units)	NERI_N06	MEADOW CREEK	2	60	3%	Jul-90	Jun-95	6.4	8.9	7.72	NA
Fecal Coliform (CFU/100mL)	NERI_N07	LAUREL CREEK AT QUINNIMONT	2	60	3%	May-90	Jun-95	1	293	33.11	NA
Iron (ug/L as Fe)	NERI_N07	LAUREL CREEK AT QUINNIMONT	1	8	13%	Jul-92	Apr-95	32	1225	331.50	NA
pH (Standard Units)	NERI_N07	LAUREL CREEK AT QUINNIMONT	2	62	3%	Jul-90	Jun-95	5.3	8.8	7.77	NA
Fecal Coliform (CFU/100mL)	NERI_N08	NEW RIVER AT PRINCE	6	60	10%	May-90	Jun-95	3	480	54.43	NA
Iron (ug/L as Fe)	NERI_N08	NEW RIVER AT PRINCE	1	9	11%	Jul-92	Apr-95	35	1491	485.22	NA
pH (Standard Units)	NERI_N08	NEW RIVER AT PRINCE	1	61	2%	Jul-90	Jun-95	5.9	9	7.89	NA
Fecal Coliform (CFU/100mL)	NERI_N09	PINEY CREEK AT MCCREERY	22	59	37%	May-90	Jun-95	16	9900	621.61	+
Iron (ug/L as Fe)	NERI_N09	PINEY CREEK AT MCCREERY	2	9	22%	Jul-92	Mar-95	48	2120	512.55	NA
Specific Conductance	NERI_N09	PINEY CREEK AT MCCREERY	12	54	22%	Jun-91	Jun-95	109	404	258.06	-
Fecal Coliform (CFU/100mL)	NERI_N10	SLATER'S CREEK AT THAYER	3	16	19%	May-90	Sep-91	3.75	593	99.61	+
Fecal Coliform (CFU/100mL)	NERI_N11	DUNLOUP CREEK	35	55	64%	May-90	Jun-95	18	3000	392.59	-
Iron (ug/L as Fe)	NERI_N11	DUNLOUP CREEK	1	9	11%	Jul-92	Apr-95	65	3046	586.89	NA
pH (Standard Units)	NERI_N11	DUNLOUP CREEK	3	54	6%	Aug-90	Jun-95	6	8.9	8.11	NA
Specific Conductance	NERI_N11	DUNLOUP CREEK	40	48	83%	Jul-91	Jun-95	143	600	433.65	+
Fecal Coliform (CFU/100mL)	NERI_N12	NEW RIVER AT THURMOND	3	55	5%	May-90	Jun-95	1	500	60.53	NA
Fecal Coliform (CFU/100mL)	NERI_N13	ARBUCKLE CREEK	29	53	55%	May-90	Jun-95	20	3940	544.40	+
Iron (ug/L as Fe)	NERI_N13	ARBUCKLE CREEK	2	9	22%	Jul-92	Apr-95	97	1744	494.33	NA

Specific Conductance	NERI_N13	ARBUCKLE CREEK	34	47	72%	Jul-91	Jun-95	153	550	396.57	+
Fecal Coliform (CFU/100mL)	NERI_N14	MANNS CREEK	1	5	20%	Jul-91	Sep-91	180	280	232.00	NA
Fecal Coliform (CFU/100mL)	NERI_N15	COAL RUN	20	52	38%	May-90	Jun-95	20	4333	323.71	+
Iron (ug/L as Fe)	NERI_N15	COAL RUN	1	9	11%	Jul-92	Apr-95	80	1644	452.11	NA
pH (Standard Units)	NERI_N15	COAL RUN	2	54	4%	Sep-90	Jun-95	6.1	8.5	7.75	NA
Specific Conductance	NERI_N15	COAL RUN	29	47	62%	Jul-91	Jun-95	100	435	332.06	-
Dissolved Oxygen (mg/L)	NERI_N16	KEENEY CREEK	1	42	2%	May-91	Jun-95	3	12.6	8.93	NA
Fecal Coliform (CFU/100mL)	NERI_N16	KEENEY CREEK	51	54	94%	May-90	Jun-95	28	36000	3579.40	+
pH (Standard Units)	NERI_N16	KEENEY CREEK	7	53	13%	Aug-90	Jun-95	6	8	7.24	+
Fecal Coliform (CFU/100mL)	NERI_N17	NEW RIVER AT FAYETTE STATION	8	55	15%	May-90	Jun-95	3	1410	110.71	-
Iron (ug/L as Fe)	NERI_N17	NEW RIVER AT FAYETTE STATION	1	9	11%	Jul-92	Apr-95	41	1112	377.22	NA
Specific Conductance	NERI_N17	NEW RIVER AT FAYETTE STATION	1	47	2%	Jul-91	Jun-95	90	460	155.72	NA
Dissolved Oxygen (mg/L)	NERI_N18	WOLF CREEK	1	43	2%	May-91	Jun-95	1.06	13	9.70	NA
Fecal Coliform (CFU/100mL)	NERI_N18	WOLF CREEK	18	54	33%	May-90	Jun-95	2	2000	204.67	+
Specific Conductance	NERI_N18	WOLF CREEK	33	47	70%	Jul-91	Jun-95	150	600	389.17	-
Dissolved Oxygen (mg/L)	NERI_N19	MARR BRANCH	15	41	37%	Jun-91	Jun-95	0.1	12.6	5.25	NA
Fecal Coliform (CFU/100mL)	NERI_N19	MARR BRANCH	44	52	85%	May-90	Jun-95	58	91000	12310.60	NA
Iron (ug/L as Fe)	NERI_N19	MARR BRANCH	4	9	44%	Jul-92	Apr-95	82	27200	3674.00	NA
pH (Standard Units)	NERI_N19	MARR BRANCH	5	52	10%	Aug-90	Jun-95	6.2	7.9	7.27	+
Specific Conductance	NERI_N19	MARR BRANCH	23	46	50%	Jul-91	Jun-95	75	1100	389.46	-
Fecal Coliform (CFU/100mL)	NERI_N20	NEW RIVER AT CUNARD	3	37	8%	Apr-92	Jun-95	3	336	69.31	NA
Iron (ug/L as Fe)	NERI_N20	NEW RIVER AT CUNARD	1	9	11%	Jul-92	Apr-95	31	1034	390.56	NA
Fecal Coliform (CFU/100mL)	NERI_N21	NEW RIVER AT SANDSTONE FALLS	4	30	13%	May-93	Jun-95	7	1100	117.46	+
Iron (ug/L as Fe)	NERI_N21	NEW RIVER AT SANDSTONE FALLS	4	8	50%	Jun-93	Apr-95	47	1232	644.63	NA
pH (Standard Units)	NERI_N21	NEW RIVER AT SANDSTONE FALLS	2	36	6%	May-93	Jun-95	7.6	9.1	8.30	NA

Notes: 1) "Exceedances" refers to the number of times observed values exceeded the threshold criteria used for any given parameter.

3) For "Trend", a "+" indicates an upward trend in observed concentrations or counts, and "-" indicates a downward trend, and "NA" indicates no obvious trend.

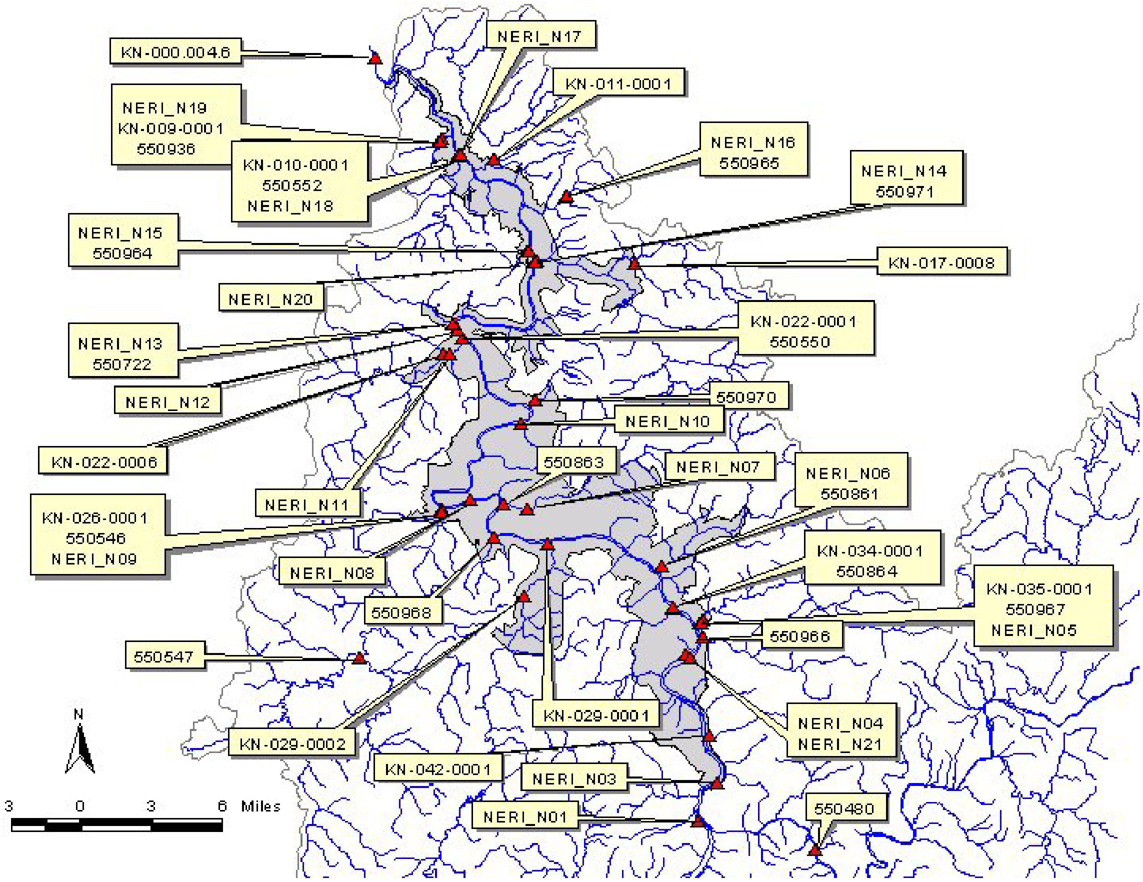
Figure 7. Location of impaired streams within the park boundary.



Fecal Coliform bacteria levels were used as an indicator of failing sewage treatment facilities or otherwise untreated wastewater upstream of a sampling point. In discussion of indicator bacteria, it should be noted that the EPA recommends the analysis of either E. Coli or enterococci bacteria for this purpose. However, there are very few samples of E. Coli and enterococci bacteria available for assessment of aquatic ecosystem health. Therefore, Fecal Coliform data were examined using an EPA (2002b) established threshold of 200 colony forming units (CFU).

High loads and or concentrations of *Total Nitrogen, Total Phosphorus, and Total Suspended Sediment* are often correlated with excessive fertilization of agricultural land, ineffective agricultural management strategies, high levels of impervious surface area, and other anthropogenic disturbances within the watershed. No nationally recognized criteria exist for these three parameters, so criteria published by Sheeder and Evans (2004) were employed. The criteria were developed for the state of Pennsylvania, and are though to be relatively accurate for regions of New York and West Virginia as well. The criteria for total nitrogen, total phosphorus, and total suspended sediment are 2.01 mg/L, 0.07 mg/L, and 197.27 mg/L respectively.

Figure 8. Location of water quality monitoring stations.



Elevated concentrations of *Mercury, Iron, Aluminum, and Manganese* and many other metals are commonly associated with large-scale disturbances within a watershed including mining and large-scale construction projects. Elevated metals concentrations can also result from acidic deposition, low watershed acid buffering capacity, and other factors. These four metals were selected from the larger suite of metals associated with mining/disturbance impairments because each has been explicitly implicated as the cause of impairment in section 303d-listed watersheds in Pennsylvania, West Virginia, New York and/or New Jersey. The EPA has published criterion for each of the metals analyzed in this report (USEPA, 2002c). Mercury is designated as a priority pollutant, and has a freshwater CMC criterion of 1.4 ug/l. Iron, Aluminum and Manganese are listed as non-priority pollutants. Iron and Aluminum are assigned freshwater criteria of 1000 ug/L (CCC) and 750 ug/L (CMC) respectively. There is no freshwater criterion set for Manganese. In the absence of an aquatic health criterion, the EPA human health consumption criterion of 50 ug/L was used to define exceedances.

Dissolved Oxygen concentration is the final parameter selected for analysis in this report. Dissolved oxygen concentrations above designated thresholds are essential for the survival of aquatic vertebrates and invertebrates, while low values suggest nuisance algae populations stemming from nutrient pollution. Several different criteria have been specified, due to the varying tolerances of adult and juvenile, warm water and cold water species. For the purposes of this investigation, the one-day minimum, coldwater fishery criterion of 4 mg/L (USEPA, 1986) is employed. This criterion is thought to be the most appropriate because the limit will include all warm water violations, without including samples that would be flagged using the coldwater, juvenile fish criteria (juvenile fish are prevalent during the spring, when mechanical saturation provides sufficient oxygen levels in all but the most impaired watersheds. These watersheds will be identified using the one-day minimum coldwater fishery criteria or via one of the other chemicals).

From the results in Table 5, it can be seen that the New River, as well as streams within and in the immediate vicinity of the New River, have water quality problems, with the primary problems being related to mine drainage (pH, aluminum, iron, manganese, and specific conductance) and high fecal coliform levels. Given that much of the data analyzed is from the mid-90s, it is possible that the nature of some of the problems noted may have changed in the intervening years since. Brief stream-by-stream assessments are provided below:

Greenbrier River

The Greenbrier River was identified on West Virginia's 303d list as being impaired by dissolved aluminum. This particular problem was evident during the 1990-1995 time period as well. Problematic levels of other mine drainage-related parameters such as iron, manganese and pH were also evident during this time frame. Although not listed for fecal coliform problems, several high observed values were noted at this same time.

Piney Creek

This stream has been 303d-listed for fecal coliform impairments, and high fecal coliform levels were evident in 1994. Additionally, problems with mine drainage were evident at different times and at different sampling points in the Piney Creek watershed from 1990 to 1999 indicating that perhaps this problem was either overlooked as a potential impairment or the problem has diminished since the mid-90s.

Dunloup Creek

The portion of Dunloup Creek that flows through the park has not been 303d-listed for any impairments; although a tributary in the headwaters (Mill Creek) has been listed for biological impairment (CNA-Biological) from unknown sources.. Although the lower reaches of this creek were not identified as being impaired, there were a number of exceedances noted for mine drainage-related parameters as well as fecal coliform during the 1990s. It may be that either these problems were overlooked as potential sources of impairment or the problems have diminished over time.

Wolf Creek

Wolf Creek has been 303d-listed due to biological impairment from unknown sources (CNA-Biological) and fecal coliform. During the 1990s, this stream experienced problems with mine drainage-related parameters such as aluminum, manganese, and specific conductivity; and it is very possible that this drainage was the source of this impairment. The listing for fecal coliform is substantiated by the high fecal coliform levels noted during the mid-1990s, and by the fact that the trend appeared to be increasing during that time.

Arbuckle Creek

Arbuckle Creek has been 303d-listed due to biological impairment from unknown sources (CNA-Biological) and fecal coliform. During the early and mid 1990s, this stream experienced problems with mine drainage-related parameters such as iron and specific conductivity; and it is very possible that this drainage was the source of this impairment. The listing for fecal coliform is substantiated by the high fecal coliform levels noted during the mid-1990s, and by the fact that the trend appeared to be increasing at the same time.

Meadow Creek

Meadow Creek has been 303d-listed for fecal coliform. This stream appeared to have some minor problems with mine drainage during the early 1990s, but these problems seem to have diminished over time. During the mid 1990s, however, problems with high fecal coliform levels were evident, and there appeared to be an upward trend during this time period.

Farley Creek

This stream has been 303d-listed for biological impairment due to unknown sources (CNA-Biological). However, based on the paucity of samples taken (i.e., 4 samples in 1990 and 1 sample in 1999) it is difficult to surmise what might be causing the problem.

Marr Branch

Marr Branch is 303d-listed for fecal coliform and biological impairments due to unknown sources (CNA-Biological). In this case, the high fecal counts noted in Table 5 may be from untreated wastewater from nearby developed and pasture areas. This could possibly explain some of the low dissolved oxygen values reported for this stream as well. Mine drainage as indicated by problematic iron, pH, aluminum, and manganese levels during the early and mid 1990s may also be an issue with this stream.

Coal Run

Coal Run has been 303d-listed for fecal coliform, and this problem is borne out by the number of exceedances noted during the early and mid 1990s.

Keeney Creek

Keeney Creek has been 303d-listed for fecal coliform, and this problem is borne out by the number of exceedances noted during the early and mid 1990s, and by the fact that there seems to be an upward trend. The paucity of other types of samples taken makes it difficult to comment on other problems that this stream may be experiencing.

Lick Creek

This stream has been 303d-listed for fecal coliform, and this problem is borne out by the number of exceedances noted during the early and mid 1990s. In this case, the high fecal counts noted in Table 5 may be from untreated wastewater from nearby developed land and pasture areas.

Fern Creek

Fern Creek has not been listed for any stream impairments. However, each of the samples for fecal coliform, manganese, and pH were noted as exceedances in Table 5, thereby suggesting that future sampling for this stream reach may be warranted.

Floyd Creek

This stream has been 303d-listed for biological impairments due to unknown sources (CNA-Biological), and iron and manganese due to mine drainage. Although the listed reach does not fall within the park boundary, it does drain directly into it (see Figure 7). One-time grab samples for these two parameters were high in 1999 as noted in Table 5.

Glade Creek

The upper reaches of Glade Creek (to the west of the New River) have been 303d-listed for fecal coliform impairments. Although the downstream end was not listed, high fecal coliform counts noted for two grab samples taken in 1999 (KN-029-0001 and KN-029-0002) suggest that further sampling of the lower reaches for this parameter might be warranted in the future.

Brooks Branch

Brooks Branch has been 303d-listed due to biological impairments due to unknown sources (CNA-Biological). Due to the complete lack of sampling data available, it is not possible to speculate what the reason for this impairment might be.

New River

The entire length of the New River within the park has been 303d-listed due to dissolved aluminum and fecal coliform. As seen in Table 5, fecal coliform criteria for the New River had been exceeded a number of times at seven different monitoring stations (NERI_N01, NERI_N03, NERI_N04, NERI_N08, NERI_N17, NERI_N20 and NERI_N21) during the early and mid

1990s. Although not listed specifically for iron, this metal also seems to be evident in high concentrations along different stretches of the New River. In any case, mine drainage appears to have had a negative impact on the river as well. (Interestingly enough, although the New River was listed for aluminum impairment, there are no aluminum exceedances noted in the record of observed data for this river). The elevated fecal coliform loads appear to originate from rural sources of untreated wastewater throughout the New River watershed (including urban and pasture land sources immediately surrounding the park), as well as sewage treatment plants located in and around the park.

In addition to the water quality trend analyses described above, mean annual loading rates for selected pollutants in parts of the larger watershed were also calculated. More specifically, loading rates were estimated for the Greenbrier River watershed identified earlier in Figure 3 as "Sub-area 2". It was not possible to calculate loading rates for any other areas since water quality monitoring stations and USGS flow gages were not co-located in any other area.

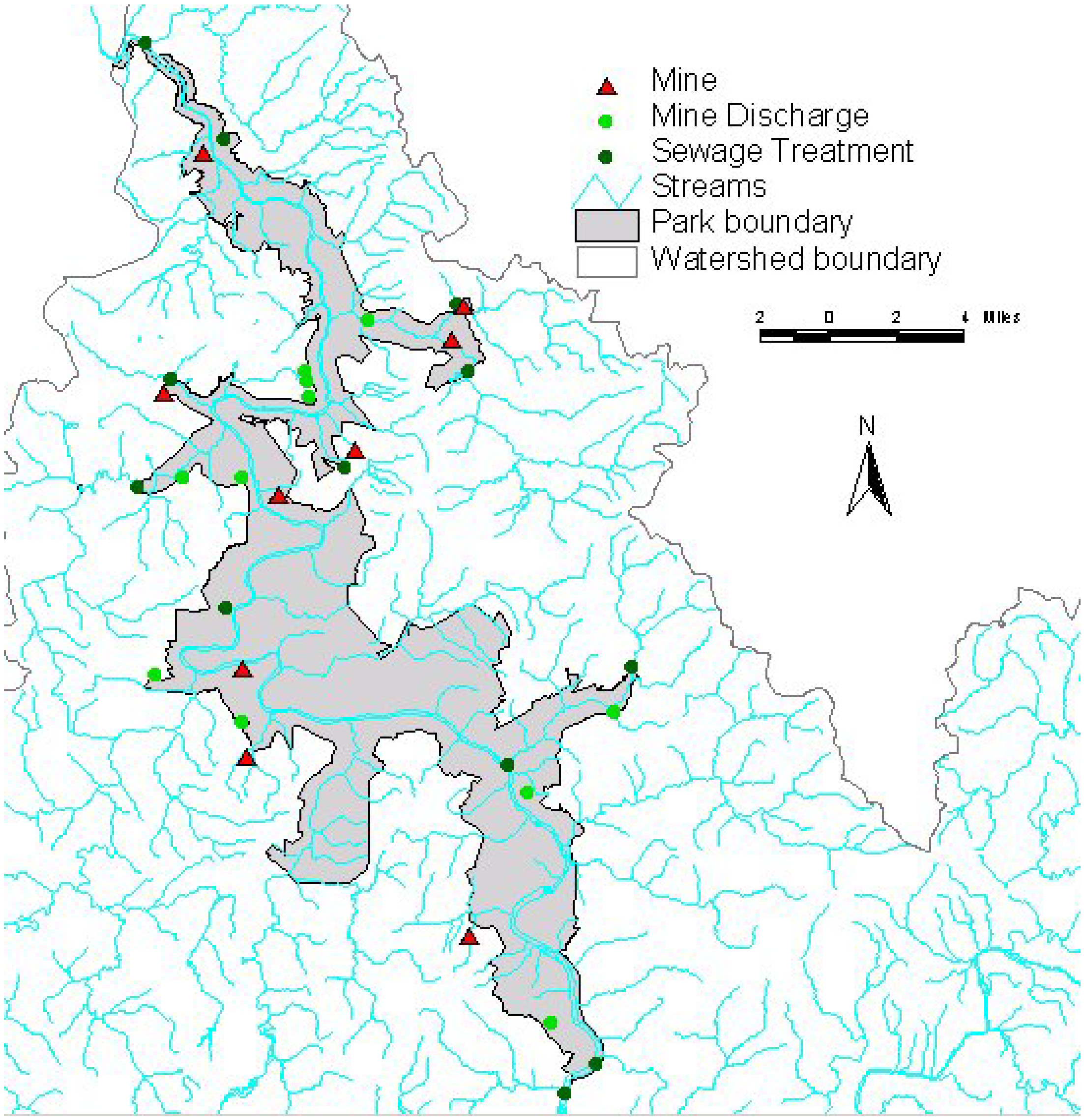
In this case, loading rates were estimated for total nitrogen and total phosphorus. A loading rate for total suspended solids (TSS; essentially, total suspended sediment) was not estimated since in-stream TSS data were not available for this station. These estimates were subsequently compared with "threshold" loading rates developed by Sheeder and Evans (2004) for evaluating watersheds in Pennsylvania. These threshold values (see Table 6) reflect values above which watersheds are believed to show signs of water quality impairment. Based on these particular criteria, it appears that nutrient and sediment loads do not represent a significant water quality problem in the Greenbrier River watershed. By extension, these results suggest that agricultural sources (i.e., via soil erosion and nutrient applications) may not be important sources of pollution in the park or surrounding areas.

Table 6. Estimated and threshold loading rates (in kg/ha per year).

Area	**USGS Gage**	**WQ Station**	**TSS**	**TN**	**TP**
Sub-Area 2	3184000	550480	NA	3.7	0.11
Threshold value	-	-	785.3	8.6	0.30

According to the Horizon report, there were 89 industrial/municipal dischargers located within the study area surrounding the New River Gorge NR. About three-quarters of these facilities appear to be either mine-related discharges or sewage treatment facilities, which ranged in size from small operators such as restaurants to larger municipal treatment plants. Given the fecal coliform and mine drainage impairments for which the New River and its' tributaries have been listed, it is certainly possible (and probable) that these facilities are having some level of impact on water quality within the park. Of these 89 dischargers, 23 of them are located in or immediately adjacent to the park boundary (see Figure 9). As shown in Figure 9, some of these are sewage treatment-related, whereas others are related to permitted mine discharges. Also, depicted in this figure are known areas of mining activity.

Figure 9. Location of municipal/industrial dischargers within the park boundary.



TMDL Development

The West Virginia Department of Environment Protection (DEP) is planning to conduct total maximum daily load (TMDL) assessments for the impaired waters in and around the park discussed in previous sections. A TMDL is essentially a plan of action used to clean up streams that are not meeting water quality standards. The plan includes pollution source identification and strategy development for contaminant source reduction or elimination. As of the date of this document (September 2004), no TMDLs have been developed for any of the "303d-listed" waters within the Lower New River watershed, including those within the New River Gorge NR. Similarly, no TMDLs have been developed in the upstream portions of the larger New River watershed (i.e., the Upper New River [which includes the Bluestone River] and the Greenbrier River).

Currently, the West Virginia DEP has plans to develop TMDLs for all of the impaired waters (with some exceptions) in the Lower New River, Upper New River, and Greenbrier River watersheds by the end of 2007. The two exceptions are the New and the Greenbrier Rivers. While fecal coliform TMDLs for these two rivers are scheduled to be completed by 2007, the dissolved aluminum TMDLs for both are not scheduled to be completed until 2017.

Presence of Existing Gages and Monitoring Sites

At present, there are only two active USGS stream flow gages located in or near the New River Gorge NR. One of these (3184500) is located on the New River just south of the southern tip of the park near the town of Hinton. The other (3185400) is located near the town of Thurmond, about 19 miles upstream from the northern edge of the park. With respect to water quality monitoring stations, there do not appear to be any active, long-term stations located in, or in the immediate vicinity of, the park. All of the stations cited in Table 3 have been discontinued, or were only set up for short-term, intensive sampling campaigns.

Recommendations for Future Monitoring

Based on the analyses presented above, it appears that elevated fecal coliform levels and problems related to mine drainage are still a source of concern for waters flowing into and through the New River Gorge NR area. As described earlier, about 44% (or about 73 miles) of the streams in the park have been included on West Virginia’s 303d list because of high fecal coliform levels, mine drainage, and or biological impairments from unknown sources (in most cases, probably due to mine drainage). As illustrated by the data in Table 5, a number of water quality monitoring stations were used to monitor these problems in the New River, as well as numerous tributaries that flow into it. As noted earlier, however, these stations have since been discontinued. These or similar stations need to be re-established in order to properly assess various problems in preparation for TMDL assessments to be completed in the New River Gorge NR and surrounding area in the future.

As discussed in a previous section, the West Virginia DEP is planning to complete most of the required TMDLs for 303-listed waters in the Lower New River, Upper New River, and Greenbrier watersheds by the end of 2007. Two exceptions are the dissolved aluminum TMDLs to be done for the New and Greenbrier Rivers by 2017. It is likely that the DEP will conduct “pre-TMDL” stream sampling in these streams as it is currently doing for other targeted areas in West Virginia. However, it is not known when this will occur. In the meantime, it might be worth considering the re-establishment of a number of water quality monitoring near the sites of previous stations; particularly those that were on impaired streams or streams that warrant further investigation as demonstrated by results provided earlier in Table 5. Recommendations on where potential monitoring stations might be established, and the types of data to be collected, are provided in summary format in Table 7.

Table 7. Recommended water quality station locations and parameters to be monitored.

Site Location	Stream Monitored	Parameters
Near old KN-000-004.6	New River (below park)	FC, DO, Fe, Al, Mn, TN, TP, TSS, pH
Near old 550936	Marr Branch	FC, DO, Fe, Al, Mn, pH
Near old 555052	Wolf Creek	FC, Fe, Al, Mn, pH
Below old KN-011-0001	Fern Creek	FC, Fe, Al, Mn, pH
Below old 550965	Keeney Creek	FC
Near old 550964	Coal Run	FC
Below old KN-017-008	Floyd Creek	Fe, Al, Mn, pH
Near old 550971	Manns/Glade Creek	Fe, Al, Mn, pH
Near old NERI_N13	Arbuckle Creek	FC, Fe, Al, Mn, pH
Near old 550550	Dunloup Creek	FC, Fe, Al, Mn, pH
Near old NERI_N10	Slater's Creek	FC
Near old 550546	Piney Creek	FC, Fe, Al, Mn, pH
Near old KN-029-0002	Glade Creek	FC, Fe, Al, Mn, pH
Near old 550861	Meadow Creek	FC
Near old 550864	Farley Creek	FC, DO, Specific Conductance
Near old 550967	Lick Creek	FC, DO, Fe, Al, Mn, TN, TP, TSS, pH
Near old KN-042-0001	Brooks Branch	Fe, Al, Mn, pH
Above old NERI_N03	New River	FC, DO, Fe, Al, Mn, TN, TP, TSS, pH

Literature Cited

National Park Service. 1995. Baseline Water Quality Data Inventory and Analysis: New River Gorge National River, Tech. Report NPS/NRWRD/NRTR-95/75, 787 pp.

Sheeder, S. A. and B.M. Evans, 2004. Estimating Nutrient and Sediment Threshold Criteria for Biological Impairment in Pennsylvania Watersheds. Journal of the American Water Resources Association (JAWRA) 40(4): 881-888.

USEPA (U.S. Environmental Protection Agency), 2002a. List of Drinking Water Contaminants & MCLs. EPA 816-F-02-013, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2002b. Implementation Guidance for Ambient Water Quality Criteria for Bacteria. EPA-823-B-02-003, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2002c. National Recommended Water Quality Criteria: 2002. EPA-822-R-02-047, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 1986. Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003, U.S. Environmental Protection Agency, Washington, D.C.

WATER QUALITY SUMMARY

for

UPPER DELAWARE SCENIC AND RECREATIONAL RIVER

September 2004

Overview of Park/Watershed Characteristics

The authorized boundary of the Upper Delaware Scenic and Recreational River (UPDE) property is approximately 75,000 acres (117 mi^2) in size (currently, the NPS owns 30 acres), and is almost entirely forested (85%) with small amounts of agricultural land (3%) and low intensity development (2%) distributed throughout the park. The river system accounts for the remaining area (10%). The watershed within which the park is located is depicted in Figure 1. The watershed is 1,966,000 acres (3,072 mi^2) in size. The land use/cover within this watershed is approximately 84% woodland, with the remaining 16% comprised of agricultural land (11%), wetlands and open water (3%) and other insignificant land cover types (<2%).

Figure 1 depicts the USGS stream discharge monitoring stations that are used to calculate contributions of discharge and pollutant loading rates generated in different portions of the Upper Delaware River watershed. As measured at the USGS gage downstream of the park, the mean daily surface water flow within the Delaware River at the Delaware Water Gap (USGS gage 1446500) is about 7776 cfs, based upon a period of record between 1922 and 2002. Eliminating all flow data prior to 1990 from the analysis yields a mean daily surface water flow of 7495 cfs indicating that flow conditions in the Delaware river between 1990 and 1996 reflect slightly lower flow conditions than the average conditions recorded over the entire period of record. Temporal variations in flow on a mean annual basis are depicted in Figure 2.

For the purposes of this analysis, various sub-watersheds within the larger watershed have also been defined based on the location of other USGS gages as shown in Figure 1. Table 1 presents information on the relative contributions of each of these smaller sub-watersheds in terms of area and mean annual flows (These gages are also used in the estimation of nutrient and sediment loading rates as described later in this report). Sub-area 1 corresponds to USGS gage 1434000 and is essentially the drainage area for the Delaware River beginning at the downstream boundary of UPDE (the gage is approximately 4 miles downstream from the park boundary). Sub-area 2 corresponds to the Delaware River drainage upstream of USGS gage 1428500 located above the confluence with the Lackawaxen River, near Barryville, NY. Sub-area 3, represented by USGS gage 1427510 is the Delaware River watershed upstream of Callicoon, NY. The East Branch of the Delaware River upstream of Fish's Eddy, NY corresponds to sub-area 4.

Figure 1. Location of park, watershed outlet, sub-areas, and USGS gages.

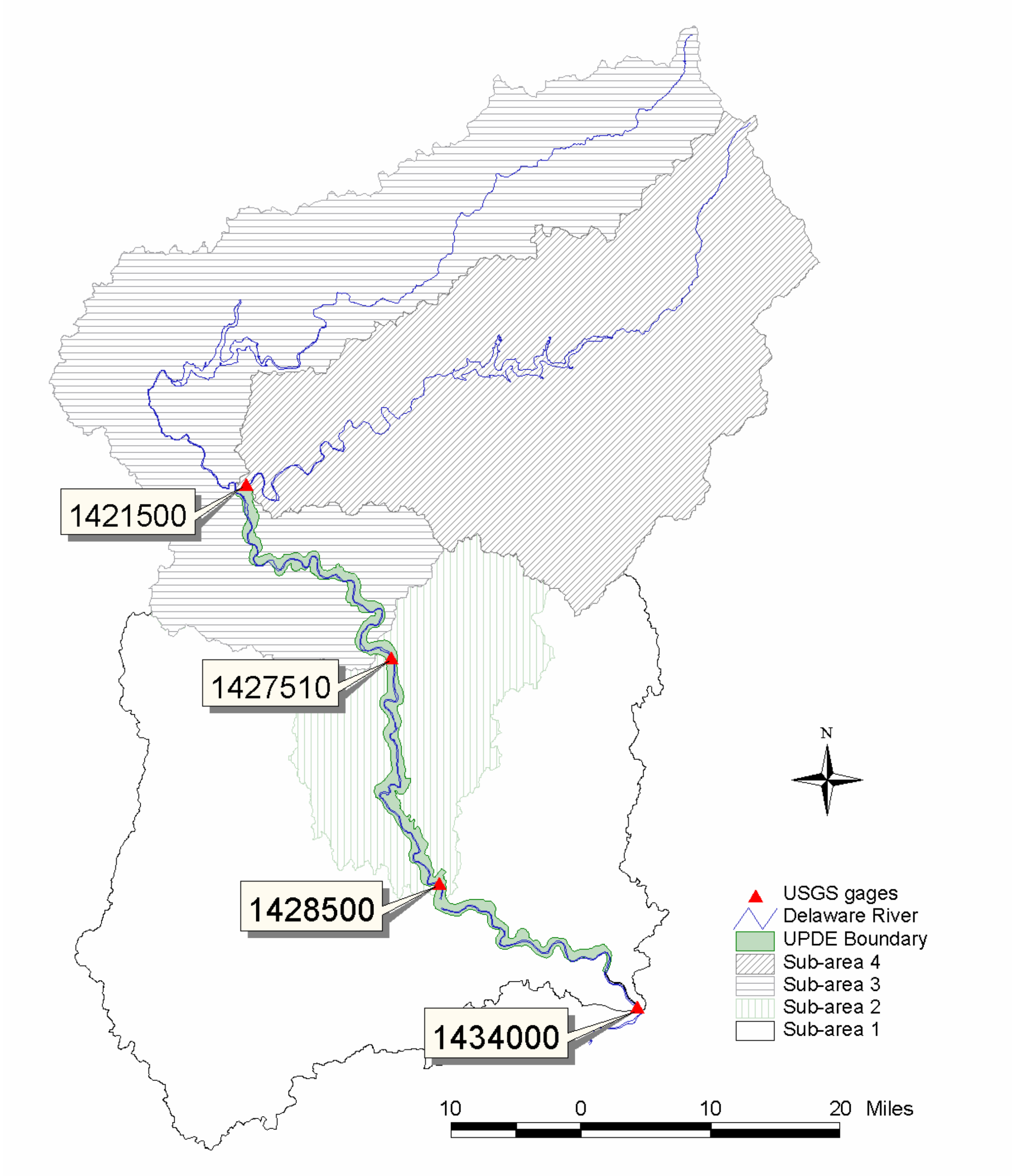


Figure 2. Representative mean annual hydrograph of flows for the Upper Delaware River at gage 1434000, approximately 4 miles downstream of the downstream boundary of UPDE (derived from 1904 – 2002 data)

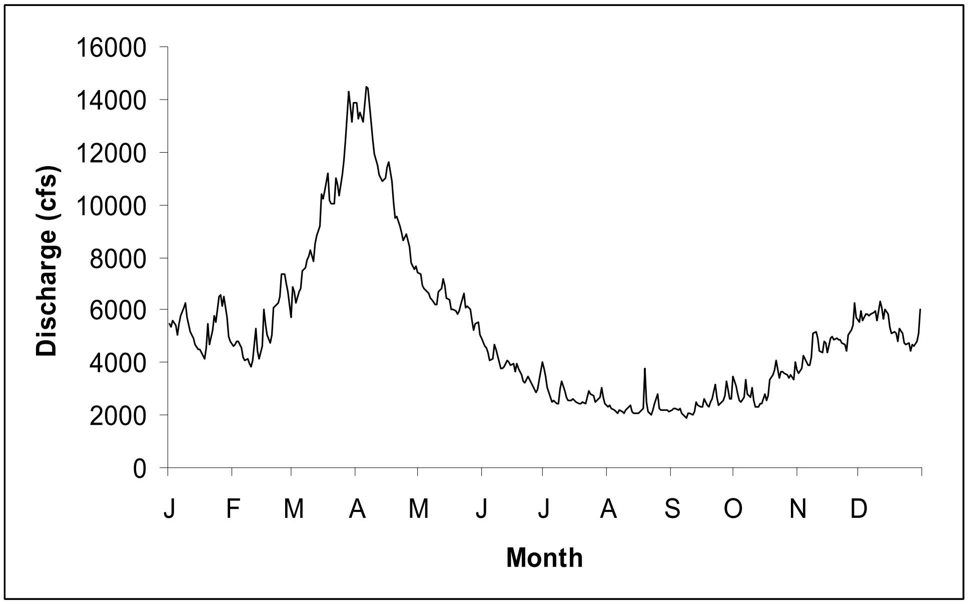


Table 1. Flow characteristics of sub-areas.

Watershed	USGS Gage	Mean Daily Flow (cfs)	% of Total Drainage Area	% of Contributed Mean Annual Flow
Sub-area 1	1434000	5162	100.0%	100.0%
Sub-area 2	1428500	3221	65.9%	62.4%
Sub-area 3	1427510	2622	55.5%	50.8%
Sub-area 4	1421500	1397	27.3%	27.1%

Historical Water Quality Overview

Detailed analyses of water quality within and around the Upper Delaware Scenic and Recreational River, as well as other national parks, has previously been prepared by the Water Resources Division (WRD) of the National Park Service (NPS, 1995). These reports are commonly referred to as "Horizon" reports after the contractor that performed most of the analyses (Horizon Systems). A Horizon report was completed for the Delaware Water Gap NRA and the Upper Delaware Scenic and Recreational River (UPDE) using data collected between 1950 and 1993 (sulfate and nitrate data extend as far back as 1923, all other parameters were measured beginning in 1950 or later) at sites located within a region extending three miles upstream and one mile downstream of the park boundaries. Based upon these temporal and spatial criteria, data from 105 water chemistry sampling stations, 35 stream discharge gaging stations, and 35 industrial/municipal dischargers were retrieved from a variety of federal and state sources (EPA, USGS, DRBC, PADEP, etc.).

In the Horizon report, it was noted that 20 different water quality parameters exceeded the screening criteria used in the study at least once within the study area. Dissolved oxygen, pH, cadmium, copper, lead, mercury, zinc, enterococci, total residual chlorine, nitrite, nitrate, nitrite plus nitrate, sulfate, cadmium, nickel, vinyl chloride, methylene chloride, coliform bacteria (total and fecal) concentrations, and turbidity each exceeded one or more of the screening criteria. Screening limits used include the WRD primary body contact recreation and aquatic life criteria, EPA drinking water criteria, and EPA criteria for the protection of freshwater aquatic life. Based on the results of this study, it was believed by the authors that surface waters within the study area are of generally good quality, with indications of some impacts from human activities. The authors concluded that any aquatic degradation could likely be attributed to increasing development of surrounding properties, resulting in sedimentation, increased stormwater runoff, short-circuiting septic systems, discharges from wastewater treatment facilities, and atmospheric deposition.

Many of the specific contaminant exceedances listed above may not be particularly important today either because of very low exceedance percentages (dissolved oxygen exceeded criteria 11 times out of 6658 samples, nitrate exceeded criteria 5 times out of 2479 samples), or because such exceedances occurred over 20 years ago. Additionally, because the Delaware Water Gap NRA and the Upper Delaware Scenic and Recreational River were analyzed in conjunction, many of the results are likely to only apply to one of the two parks. Separation of the Horizon Report data into separate databases representing the individual parks is beyond the scope of this analysis. Therefore, the summary of the Horizon Report results should be viewed as general guidelines only, and not assumed to represent conditions of the individual NPS park properties. Given these limitations, the Horizon report suggests that the primary pollutants of concern include pH, bacteria (total coliform, fecal coliform, and enterococci), and lead. These conclusions partially agree with the water quality analysis conducted for this report and discussed in an upcoming section. Water quality analyses using 1990-2004 data indicate that pH, fecal coliform bacteria and manganese are the major pollutants affecting water quality at UPDE. The results of this analysis are presented below.

Specially Designated Surface Water Bodies

According to the Pennsylvania and New York state geographic information system surface water files, there are over 170 miles of streams located within the UPDE park boundary that have a designated use and/or anti-degradation policy associated with the water body. Figure 3 depicts these water bodies and their associated designations. Since states are responsible for individually assessing the use and protection of surface water bodies, the surface water designations are defined differently for each state.

The Pennsylvania designations include 'high quality' (HQ) and 'exceptional value' (EV) waters. In Pennsylvania, high quality waters must meet one or more of the following conditions:

1. The water has long-term water quality (>1 year of data collection) that exceeds levels necessary to support the propagation of fish, shellfish, and wildlife and recreation in and on the water.
2. The surface water supports a high quality aquatic community based upon data gathered using peer-reviewed biological assessment procedures

Exceptional value waters must:

1. meet all requirements of high quality waters and additionally meet the requirements of one or more of the following:
    a. The water is located in a designated State park natural area, state forest natural area, National natural landmark, Federal or State wild river, Federal wilderness area or National recreation area
    b. The water is located in a National wildlife refuge or a State game propagation and protection area
    c. The water is an outstanding National, State regional or local resource water
    d. The water is a surface water of exceptional recreational significance
    e. The water is designated as a "wilderness trout stream" by the Fish and Boat Commission following public notice and comment
2. be of exceptional ecological significance.

The stream designation system employed by the state of Pennsylvania also describes surface waters from a fisheries perspective. These additional descriptions include:

1. CWF - Cold Water Fishes - Maintenance or propagation, or both, of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat
2. WWF - Warm Water Fishes - Maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat
3. MF - Migratory Fishes - Passage, maintenance and propagation of anadromous and catadromous fishes and other fishes which ascend to flowing waters to complete their life cycle.
4. TSF - Trout Stocking - Maintenance of stocked trout from February 15 to July 31 and maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.

Pennsylvania high quality and exceptional value waters are afforded additional protection in order to maintain their current status. The additional regulations include protection against point source discharging facility development, stringent controls on existing municipal and industrial dischargers, and non-point source pollution controls (best management practice implementation). Further detail on these policies can be found in Title 25, Chapter 93 of the Pennsylvania Code.

The State of New York supports three different designations; class A, class B, and class C.

1. A 'Class A' fresh surface water designation indicates that the water may be used for
    a. A source of water supply for drinking, culinary or food processing purposes
    b. Primary and secondary contact recreation and fishing

    Additionally, the waters shall be suitable for fish propagation and survival.
2. 'Class B' fresh surface waters are best used for primary and secondary contact recreation and fishing. These waters are also considered suitable for fish propagation and survival.
3. 'Class C' fresh surface waters are best used for fishing. These waters shall be suitable for fish propagation and survival. The water quality may be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.

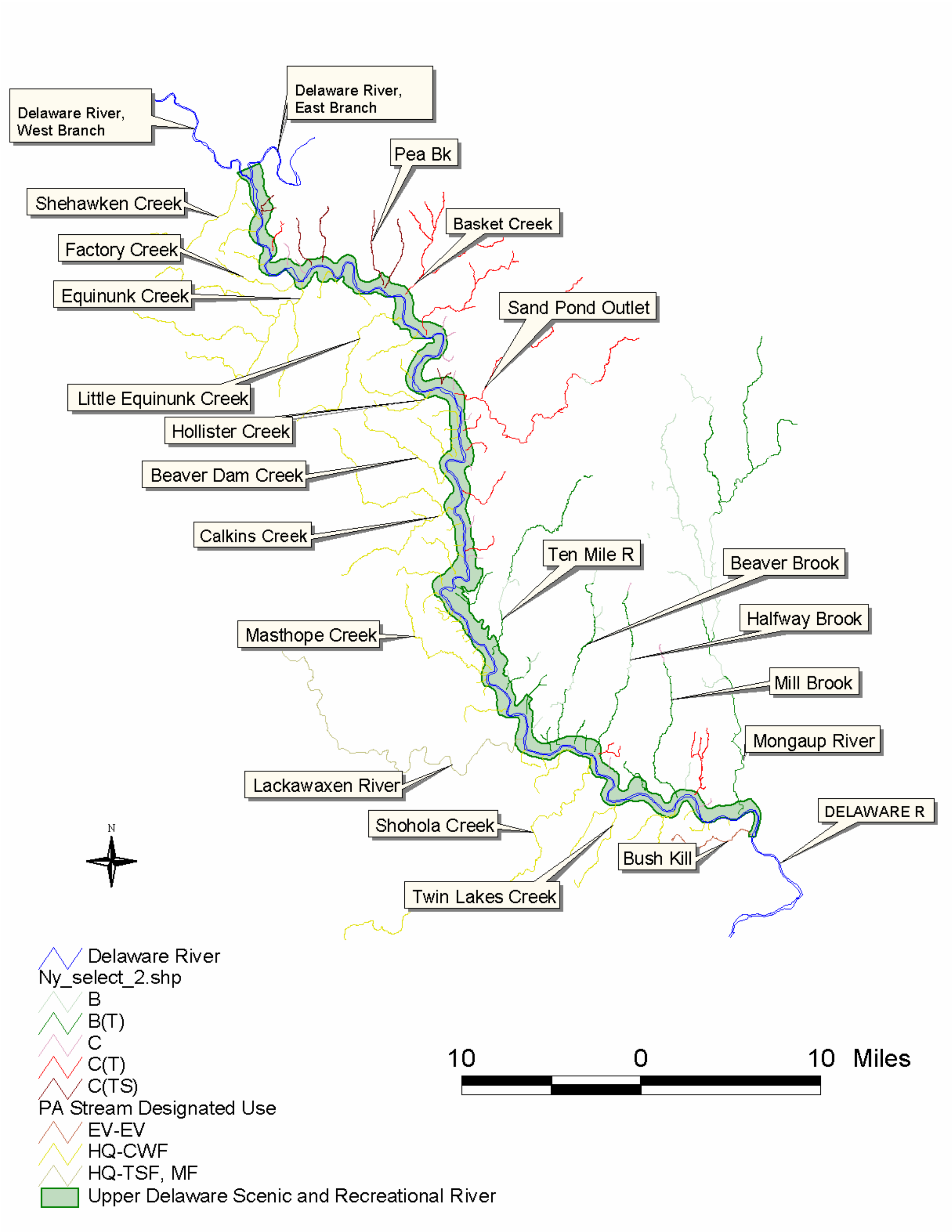
The quality of waters in New York has been further divided based upon Fish and Wildlife Commission trout survival and reproduction surveys. These surveys yield two additional designations:

1. (T): The Fish and Wildlife commission has found that the waters are suitable for trout to survive in
2. (TS): The Fish and Wildlife commission has found that the waters are suitable for trout to survive and spawn in. For the purposes of 'high quality' designations, streams with the (TS) standard will be considered a high quality stream

Section §703.2 of the New York State water quality manual can be viewed at http://www.dec.state.ny.us/website/regs/part703.html#703.2. This section, titled 'Narrative water quality standards' reviews many different water quality parameters (i.e., turbidity, suspended solids, nutrients, etc.), and how these parameters are applied to antidegradation of fresh waters within the state. While specific standards vary slightly, waters of a specific designation cannot be adversely affected to the point that the current designation no longer applies.

In December 1992, the mainstem of the Delaware River was designated as 'special protection waters' by the Delaware River Basin Commission (DRBC) with the support of the NPS. The stretch of the Delaware afforded this special protection begins upstream of the UPDE boundary and extends to the downstream boundary of DEWA, thereby encompassing both NPS properties located on the Delaware River. Associated with this special designation, DRBC has adopted a policy that states, "there be no measurable change in existing water quality except towards natural conditions" within this region. In order to evaluate changes in the existing water quality, data for 14 parameters at UPDE and 16 parameters between Millrift, PA and the downstream boundary of DEWA were collected (DRBC, 1996). These data were used to establish regulatory standards against which changes in water quality can be evaluated.

Figure 3. Streams with specific anti-degradation policies, located within the Upper Delaware Scenic and Recreational River



Current Listing of Water Quality Impairments

As shown in Figure 4, the mainstem of the Delaware River and the West Branch of the Delaware River have been identified as being impaired on the Pennsylvania Human Health 303d list. Table 2 provides information on the impaired surface water bodies either in or immediately adjacent to UPDE, and Figure 4 depicts the location of these streams. In all cases, the 'sources' have been listed as 'unknown'. The Delaware River and the West Branch of the Delaware River are listed for impairment due to Mercury contamination. It is very likely that these impairments are associated with atmospheric deposition (Mercury emission to the atmosphere is a byproduct of coal combustion) and specific properties of the chemical element, which allow Mercury to bio-accumulate in the tissue of aquatic organisms. The mainstem of the Delaware River is also listed for impairment due to PCB contamination. High concentrations of PCBs have been measured in the Delaware estuary. Similar to Mercury, PCBs accumulate in the tissue of aquatic organisms. Since the Delaware River remains free-flowing, many of these infected organisms are free to migrate throughout the Delaware River, spreading the PCB contamination from the estuary (the site of original contamination) to other reaches of the river. The Delaware River, upstream of the estuary was listed on the 303d list because 1995 samples of American Eel tissue contained elevated levels of these chemicals. For further information on the status of PCB contamination, modes of contamination, and TMDL development contact Robert Frey of the Pennsylvania State Department of Environmental Protection (717-787-9637).

Figure 4. Location of impaired surface water bodies on 303d list.

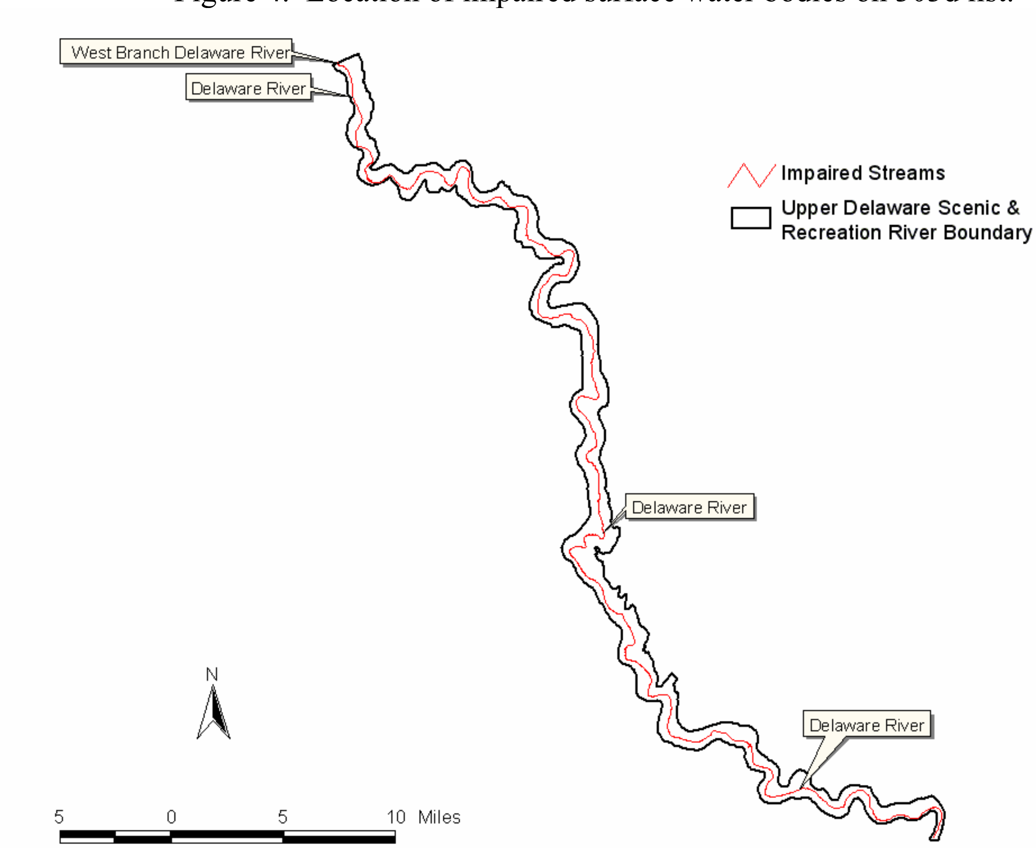


Table 2. Sources and causes of 303d listed impairments.

Surface Water Body	Cause	Source	Impaired Miles within the Park
West Branch Delaware River	Mercury	Unknown	3.4
Delaware River	Mercury, PCB	Unknown	73.6

Current Water Quality Trends and Loading Rates

Using 1990-2004 water quality data, mean annual concentration values for selected parameters were compared with criteria similar to those used in the earlier Horizon reports to assess whether potential water quality problems identified in the past still exist. These selected parameters were based on various factors, including past problems described in the Horizon report, problems identified in the 303d listings, and the list of core parameters to be used as "vital sign" indicators as identified by the NPS Water Resources Division. Temperature is also listed as one of the core parameters, but was not included here for several reasons. First, there are no established temperature criteria to use to evaluate the condition of the aquatic system. Secondly, trends in temperature could be evaluated but the results may prove misleading due to natural long-term air temperature trends and the relationship between air and water temperature (i.e. gradual warming of mean annual water temperature may reflect recent warming of the climate, and not watershed disturbance).

Temporal trends for selected water quality parameters were also determined to provide a sense of potential changes in such parameters over time (i.e., are problems getting worse or better?). Temporal trends were evaluated for each constituent that exceeded concentration criteria greater than 10% of the time during the period of analysis (1990-2003) and was measured more than ten times at a particular station. To determine the existence of a temporal trend, concentration values were plotted against date and fit with a linear trendline in MS Excel. Additionally, loading rates for various water quality parameters were estimated for the entire park drainage area and other sub-areas to provide another measure of potential water quality problems.

Based upon information provided in previous sections, water quality statistics and trends were determined for total nitrogen, total phosphorus, specific conductivity, pH, fecal coliform, mercury, iron, aluminum, manganese, and dissolved oxygen where the appropriate data were available (see Table 3). In all cases, an attempt was made to use any sample data collected from 1990 up to the present. However, as can be seen from Table 3, data from some of these sites were only as recent as 1993. These parameters were selected because they are commonly used to assess certain aspects of the hydrologic system, and are briefly discussed below. The water quality stations for which data were compiled for this analysis are shown in Figure 5.

Specific Conductivity is the ability of a substance to conduct an electrical current across a given length at a specified temperature. Specific Conductivity can be used as an indicator of water quality because pure water has a very low electrical conductance. As concentrations of different ions dissolved in water increase, so does the conductivity. Therefore, conductivity is directly related to the amount of charged particles (i.e. heavy metals, clay particles, etc.) contained within a water sample. While there are no set conductivity criteria for fresh water, specific conductance is linearly related to the concentration of total dissolved solids in a sample. For the purposes of this investigation,

$$0.65*K = S$$

where K is conductance (micromhos) and S is dissolved solids (mg/L). The EPA has a recommended criterion of 500 mg/L for dissolved solids in drinking water (US EPA, 2002a). This corresponds to a specific conductivity of 325 micromhos, given the equation above.

pH is one of the most general indicators of water quality. The natural logarithm of hydrogen ion concentration in solution, pH ranges from 0-14 with 7 being neutral. pH values ranging from approximately 6-8 naturally occur in freshwater aquatic systems. The EPA-established criterion for aquatic life protection includes pH values between 6.5 and 9.0. For the purposes of this investigation, recorded values outside of this range were flagged as an indication of impairment.

Fecal Coliform bacteria levels were used as an indicator of failing sewage treatment facilities or otherwise untreated wastewater upstream of a sampling point. In discussion of indicator bacteria, it should be noted that the EPA recommends the analysis of either E. Coli or enterococci bacteria for this purpose. However, there are very few samples of E. Coli and enterococci bacteria available for assessment of aquatic ecosystem health. Therefore, Fecal Coliform data were examined using an EPA (2002b) established threshold of 200 colony forming units (CFU).

High loads and or concentrations of *Total Nitrogen, Total Phosphorus, and Total Suspended Sediment* are often correlated with excessive fertilization of agricultural land, ineffective agricultural management strategies, high levels of impervious surface area, and other anthropogenic disturbances within the watershed. No nationally recognized criteria exist for these three parameters, so criteria published by Sheeder and Evans (2004) were employed. The criteria were developed for the state of Pennsylvania, and are though to be relatively accurate for regions of New York and West Virginia as well. The criteria for total nitrogen, total phosphorus, and total suspended sediment are 2.01 mg/L, 0.07 mg/L, and 197.27 mg/L respectively.

Elevated concentrations of *Mercury, Iron, Aluminum, and Manganese* and many other metals are commonly associated with large-scale disturbances within a watershed including mining and large-scale construction projects. Elevated metals concentrations can also result from acidic deposition, low watershed acid buffering capacity, and other factors. These four metals were selected from the larger suite of metals associated with mining/disturbance impairments because each has been explicitly implicated as the cause of impairment in section 303d-listed watersheds in Pennsylvania, West Virginia, New York and/or New Jersey. The EPA has published criterion for each of the metals analyzed in this report (USEPA, 2002c). Mercury is designated as a priority pollutant, and has a freshwater CMC criterion of 1.4 ug/l. Iron, Aluminum and Manganese are listed as non-priority pollutants. Iron and Aluminum are assigned freshwater criteria of 1000 ug/L (CCC) and 750 ug/L (CMC) respectively. There is no freshwater criterion set for Manganese. In the absence of an aquatic health criterion, the EPA human health consumption criterion of 50 ug/L was used to define exceedances.

Dissolved Oxygen concentration is the final parameter selected for analysis in this report. Dissolved oxygen concentrations above designated thresholds are essential for the survival of aquatic vertebrates and invertebrates, while low values suggest nuisance algae populations stemming from nutrient pollution. Several different criteria have been specified, due to the varying tolerances of adult and juvenile, warm water and cold water species. For the purposes of this investigation, the one-day minimum, coldwater fishery criterion of 4 mg/L (USEPA, 1986) is employed. This criterion is thought to be the most appropriate because the limit will include all warm water violations, without including samples that would be flagged using the coldwater, juvenile fish criteria (juvenile fish are prevalent during the spring, when mechanical saturation provides sufficient oxygen levels in all but the most impaired watersheds. These watersheds will be identified using the one-day minimum coldwater fishery criteria or via one of the other chemicals).

Data from 87 water quality monitoring stations within or immediately adjacent to UPDE were queried to identify cases where the chemical criteria outlined above were exceeded. These queries indicate that one or more water quality parameters exceeded the established criteria at 12 of the 87 stations that were analyzed. These exceedances of water quality criteria are summarized in Table 3. From Table 3 it can be seen that pH, fecal coliform bacteria, and manganese appear to be the predominant pollutants affecting UPDE.

In an area with very little disturbance from mining activities, likely sources of the pH problems include acidic deposition in conjunction with low buffering capacity of the underlying bedrock. High in-stream manganese concentrations are a harmful side affect of low pH precipitation. As acidic precipitation falls and percolates through the soil and unconsolidated rock layers, manganese (and potentially other metals present in the substrate) can be leached out of the contact material and carried into the river system. The presence of high levels of fecal coliform bacteria indicate that there may be a substantial number of short-circuiting and damaged septic systems in the watershed as well.

In addition to the chemical parameters discussed above, data collected at station DRBC/NPS65 indicate that Phosphorus levels in Tenmile River exceeded the established concentration criteria during the period between July 1991 and June 1993. However, trends in phosphorus concentrations were decreasing during this time period. Additionally, many sewage treatment and agricultural practices were upgraded in the early 1990's to mitigate phosphorus pollution. Given these conditions (and the loading rates discussed in an upcoming section) it appears that nutrient pollution is not a significant concern in the upper Delaware watershed.

It is interesting to note that all stations included in this analysis were analyzed for violations in the mercury criteria, with no results returned. The discrepancy between this result and the 303d listing of the Delaware River for impairment due to Mercury can be explained by the behavior of mercury in aquatic systems. Mercury is lipophylic, meaning that the metal accumulates in the fatty tissues of biological organisms. As prey organisms are consumed by predators, the mercury present in the prey species is transferred up the food chain. This results in elevated concentrations of mercury in the tissues of predatory species. Therefore, the Delaware River is listed on the PA 303d list due to elevated levels of mercury in fish tissue, while the instream concentrations remain below the established EPA criteria.

In addition to the water quality trend analyses described above, mean annual loading rates for selected pollutants in the watershed were also done. Specifically, loading rates of nitrogen, phosphorus, and suspended sediment were calculated for sub-areas 1-4 (Figure 1).

Total nitrogen, total phosphorus and total suspended sediment loading rates were estimated for each sub-area, given water quality data availability (see Table 4). These estimates were subsequently compared with “threshold” loading rates developed by Sheeder and Evans (2004) for evaluating watersheds in Pennsylvania. These threshold values (also shown in Table 4) reflect values above which watersheds are believed to show signs of water quality impairment. Based on these particular criteria, it appears that nutrient and sediment loads do not represent a significant water quality problem in the sub-areas that were analyzed. It is important to note that as mentioned earlier, phosphorus measurements did exceed the established concentration criteria at theDRBC/NPS65 site two times between July 1991 and June 1993. While phosphorus does not appear to be a problem in the Upper Delaware, future monitoring of nutrients would help to confirm this conclusion.

TMDL Development

The Pennsylvania Department of Environment Protection (DEP) is planning to conduct total maximum daily load (TMDL) assessments for the impaired waters discussed in previous sections. A TMDL is essentially a plan of action used to clean up streams that are not meeting water quality standards. The plan includes pollution source identification and strategy development for contaminant source reduction or elimination. As of the date of this document (September 2004), no TMDLs have been developed for any of the “303d-listed” waters within the Upper Delaware Scenic and Recreational River property. The PA DEP is legally mandated to complete TMDL assessments in the order that the streams are listed, and to demonstrate sufficient progress (as determined by legal court review) on an annual basis. The PA DEP is currently working on impaired water bodies listed during the 1998-2000 Assessment round. All water bodies listed after this date will be assessed in the order that they were evaluated. Currently, the PA DEP has a list of TMDLs to be completed by 2007 posted on their web site (http://www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/TMDL/TMDL_6yearplan.pdf). The Delaware River estuary and downstream (of UPDE) reaches are scheduled for TMDL assessment during the 2005-2007 time frame. However, neither the Delaware River, nor the West Branch of the Delaware River is listed in this report. Therefore, it is estimated that the TMDLs affecting the UPDE property will be conducted after the 2007 round has been completed. The state of New York is very far behind other states in the region in development of a plan for assessing waters in the state and conducting TMDL analyses on the impaired water bodies. To date, New York has not assessed water bodies within the Delaware watershed, and has no plans to complete TMDLs in the region.

Table 3. Results of analyses based on 1990-2004 water quality data at stations in and around Upper Delaware Scenic and Recreational River.

station ID	Station Name	Chemical Characteristic	Violations	Sample Count	% Violation	Begin Date	End Date	Min. Value	Max. Value	Avg. Value	Trend
DRBC/NPS21	Delaware River, Callicoon access area	Fecal Coliform	10	75	13.3%	Jun-90	Nov-98	1	1950	100	+
		pH	10	74	13.5%	Jun-90	Nov-98	6.25	9.8	7.75	NA
DRBC/NPS304	Delaware River, Callicoon Bridge	Fecal Coliform	4	38	10.5%	Aug-94	Nov-98	1	462	42	+
DRBC/NPS56	Shohola Creek, railroad bridge near confluence with Delaware River	pH	7	66	10.6%	Jul-90	Nov-98	6	7.6	6.74	+
DRBC/NPS65	Tenmile River, RT 97 Bridge	Phosphorus	2	19	10.5%	Jul-91	Jun-93	0.01	0.076	0.029	-
DRBC/NPS69	Calkins Creek, near confluence with Delaware River	Fecal Coliform	8	61	13.1%	Jul-91	Nov-98	2	800	87	+
DRBC/NPS75	Callicoon Creek, RT 97 Bridge	Fecal Coliform	17	69	24.6%	Jul-90	Nov-98	1	2980	294	-
		pH	8	69	11.6%	Jul-90	Nov-98	6.25	9.9	7.76	+
DRBC/NPS79	Little Equinunk Creek, at bridge near confluence with Delaware River	Fecal Coliform	5	38	13.2%	Jul-90	Nov-98	1	800	90	-
DRBC/NPS90	West Branch Delaware, RT 191 Bridge in Hancock, NY	Fecal Coliform	8	66	12.1%	Jul-91	Nov-98	1	1600	105	+
WQN0103	Delaware River	Manganese	12	65	18.5%	Jun-96	Feb-04	2.9	1730	63.0	NA
		pH	24	71	33.8%	Jun-96	Feb-04	6	8.46	6.70	+
WQN0104	West Branch Delaware River	Fecal Coliform	13	95	13.7%	Jan-90	Feb-02	10	1700	142	+
		Manganese	70	174	40.2%	Jan-90	Feb-04	10.6	521	62.6	+
		pH	40	149	26.8%	Jan-90	Feb-04	6.1	8.33	6.69	+
WQN0147	Lackawaxen River	Fecal Coliform	14	100	14.0%	Jan-90	Feb-02	10	2500	125	-
		Manganese	38	141	27.0%	Jan-90	Feb-04	0	421	47.1	+
		pH	37	150	24.7%	Jan-90	Feb-04	5.9	8.9	6.75	+
WQN0185	Delaware River	Fecal Coliform	3	21	14.3%	Oct-98	Feb-02	10	2200	167	NA
		pH	43	148	29.1%	Jan-90	Dec-03	6.1	8.23	6.66	+

Notes: 1) “Violations” refers to the number of times observed values exceeded the threshold criteria used for any given parameter.
2) For “Trend”, a “+” indicates an upward trend in observed concentrations or counts, and “-“ indicates a downward trend, and “NA” indicates no obvious trend.

Figure 5. Location of water quality monitoring stations used for current analysis.

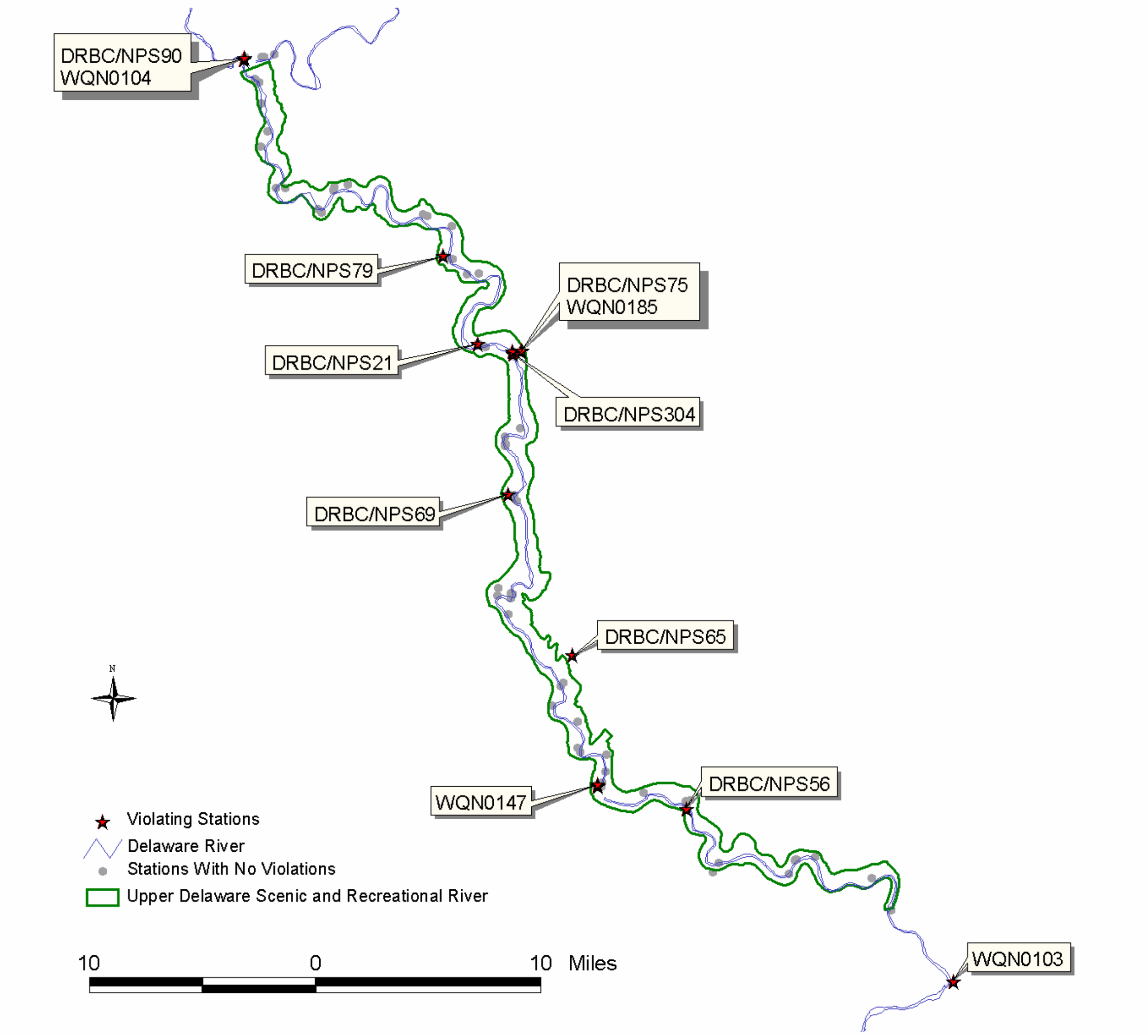


Table 4. Estimated and threshold loading rates (in kg/ha per year).

Watershed	USGS Gage	Area [ha]	TSS [kg/y/ha]	TN [kg/y/ha]	TP [kg/y/ha]
Threshold Values			785.3	8.6	0.30
Sub-area 1	1434000	797749	258.86	1.68	0.15
Sub-area 2	1428500	525392	-	2.40	0.12
Sub-area 3	1427510	442653	-	2.53	0.14
Sub-area 4	1421500	217610	211.54	3.35	0.05

Presence of Existing Gages and Monitoring Sites

At present, there are five active USGS stream flow gages in and around UPDE (Figures 1 and 6). Data from several of these gages (1427510, 1428500, 1434000) were used in the loading rate calculations described in the previous section. Unfortunately USGS gage 1421500 (Figure 1) was discontinued as of September 2001. During operation, this gage provided valuable information on discharge from the East Branch of the Delaware River just upstream of the UPDE boundary. Discharge from the East and West Branches of the Delaware is currently being measured by 1426500 and 1420980 respectively. The other three discharge monitoring stations that are currently in operation are located along the mainstem of the Delaware River. For the stations currently in operation, the USGS site number and a description of the site location are provided in Table 5.

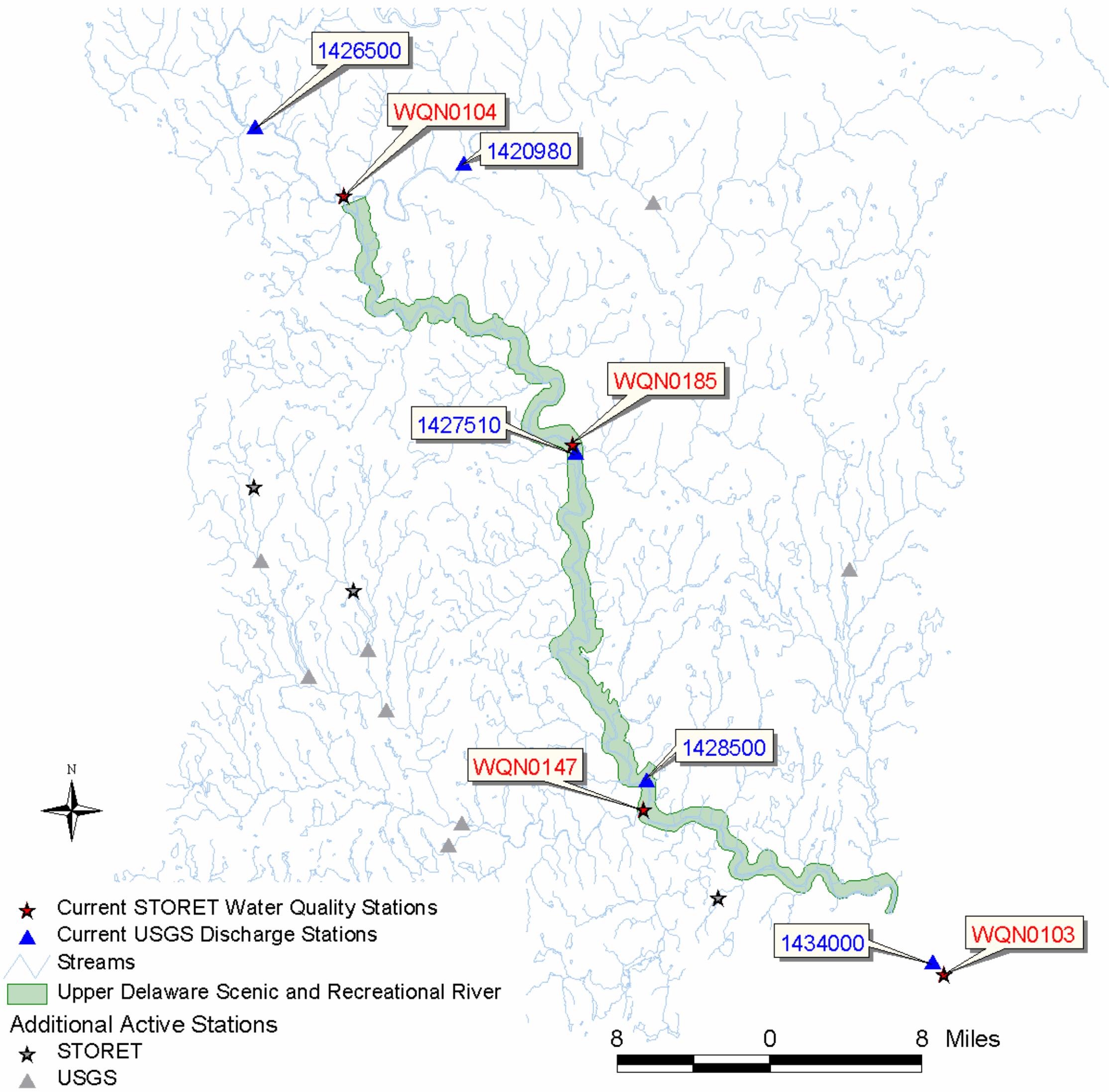
With respect to water quality monitoring stations, there are 4 stations relevant to UPDE water quality that appear to be actively compiling data in the Modern STORET database. The name and location of each of these stations is depicted in Figure 6. Based on a review of recently recorded STORET data, a fairly extensive suite of water quality parameters are being sampled on a monthly basis at these stations (maintained by the Pennsylvania DEP). These stations are collecting and analyzing water samples for metals, nutrients, and basic water quality parameter data on a monthly basis. As can be seen in Figure 6, there are other active stations within the UPDE contributing watershed. However, data collected at these sites are not relevant to park water quality due to the distances between these sites and the UPDE boundary.

Table 5. Active USGS stream gages.

USGS Station Number	Location
1426500	West Branch of the Delaware River at Hale Eddy, NY
1420980	East Branch of the Delaware River above Read Creek at Fish's Eddy, NY
1427510	Delaware River at Callicoon, NY
1428500	Delaware River above Lackawaxen River near Barryville, NY
1434000	Delaware River at Port Jervis, NY

In addition to the long-term station data available through the USGS and the USEPA, The DRBC and the NPS are collecting water quality data at sites on the Delaware River within the UPDE property. These data are being collected following a redesigned monitoring strategy (DRBC, 1995) for the mainstem of the Delaware in support of the Delaware River antidegradation policy.

Figure 6. Active USGS stream discharge gages, and STORET water quality monitoring stations.



Recommendations for Future Monitoring

Based on the analyses presented above, it appears that problems related to pH, manganese, and bacterial (fecal coliform) contamination are affecting water quality, at least to a limited extent within Upper Delaware Scenic and Recreational River surface waters. Additionally, mercury and PCB contamination of fish tissue have led to fish consumption advisories and the listing of the mainstem and West Branch of the Delaware River on the PA 303d list.

As can be concluded by comparing Legacy STORET and Modern STORET query results for the DEWA region, many stations that historically were used to monitor the Delaware

River watershed have been discontinued. It may be necessary to re-establish stations in several key drainage basins in order to properly assess nutrient, bacteria, metals, organic constituent, and pH conditions in preparation for upcoming TMDL assessments. As discussed in a previous section, the Pennsylvania Department of Environmental Protection is planning to conduct the required TMDLs for 303-listed waters in the Upper Delaware River watershed in the near future. In anticipation of this, the respective agencies will be collecting data (at least on a short-term basis) on all impaired waters. While plans for data collection by the PA DEP have not been officially announced, it may be beneficial for park managers to contact state agencies in the near future regarding this issue.

From an ecological monitoring perspective, it would be beneficial for the NPS to set up discharge and chemical monitoring stations on several of the currently un-gaged watersheds within the UPDE property. These watersheds include Tenmile River, Calkins Creek, Callicoon Creek, and Shohola Creek. These watersheds may be of interest because the water quality analysis conducted in this report indicates that these basins are sources of bacterial and pH contamination. The Bush Kill and Pea Brook basins may be of special interest due to their ‘exceptional value’ and ‘trout spawning’ designations.

A stream discharge monitoring station could be co-located with WQN0147 to provide further information on the condition of the Lackawaxen River watershed. Additionally, long-term stream discharge site 1428500 does not currently have a co-located water quality station. As previously mentioned, co-located chemistry and flow stations provide the ability to investigate pollutant loads, as well as chemical concentrations.

The extent to which these recommendations are followed will largely depend upon funding considerations. Therefore, input from New York and Pennsylvania Departments of Environmental Protection and the USGS regarding future plans for monitoring will undoubtedly prove useful in the decision making process.

Literature Cited

Delaware River Basin Commission. 1996. Administrative Manual part III: Water Quality Regulations. Delaware River Basin Commission, West Trenton, NJ. 104pp.

Delaware River Basin Commission and National Park Service. 1995. Redesign of the DRBC/NPS Scenic Rivers Monitoring Program. Report no. 18 of the DRBC/NPS Cooperative Monitoring Program. 70pp.

National Park Service. 1995. Baseline Water Quality Data Inventory and Analysis: Delaware Water Gap National Recreation Area and Upper Delaware Scenic and Recreational River, Tech. Report NPS/NRWRD/NRTR-95/42, 1403 pp.

PADEP (Pennsylvania Department of Environmental Protection), 2004. Pennsylvania DEP’s Six Year Plan for TMDL Development. http://www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/TMDL/TMDL_6yearplan.pdf (Last accessed September 27, 2004).

Sheeder, S. A. and B.M. Evans, 2004. Estimating Nutrient and Sediment Threshold Criteria for Biological Impairment in Pennsylvania Watersheds. Journal of the American Water Resources Association (JAWRA) 40(4): 881-888.

USEPA (U.S. Environmental Protection Agency), 2002a. List of Drinking Water Contaminants & MCLs. EPA 816-F-02-013, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2002b. Implementation Guidance for Ambient Water Quality Criteria for Bacteria. EPA-823-B-02-003, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2002c. National Recommended Water Quality Criteria: 2002. EPA-822-R-02-047, U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 1986. Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003, U.S. Environmental Protection Agency, Washington, D.C.